GENERAL MECHANICAL DRAWING

◆

McGEE « » STURTEVANT

Arthur A. Strong.

Arthur A. Strong

General Mechanical Drawing

Vast opportunities for work and service are open to the mechanical draftsman

General Mechanical Drawing

A Course Based on the Junior-High-School Movement

R. A. McGee, B.S., M.A.
Formerly of the
Department of Industrial Education, College of Education,
University of Minnesota, Minneapolis, Minn.

and

W. W. Sturtevant, B.S.
South High School, Minneapolis, Minn.

THE BRUCE PUBLISHING COMPANY
New York MILWAUKEE, WIS. Chicago

Copyright, 1930
The Bruce Publishing Company
Printed in the United States of America

FOREWORD

There has been a keenly felt need for some years past for textbooks in the field of industrial arts, which provide graded lessons in manipulative processes correlated with others of an informational character. These are required particularly at the junior-high-school levels, where texts designed to assist in the achievement of the "peculiar functions" of this institution are relatively scarce.

Most high-school teachers of mechanical drawing are committed to the use of some basic textbook. A generous number of drawing books designed for secondary-school use are on the market. Many of these are excellent texts. However, the need expressed in the foregoing paragraph has not been met hitherto in a wholly satisfactory manner.

Our position is made clear by outlining some of the major characteristics of a drawing book for junior-high-school use, which drawing texts in general cannot be said to possess. First, it should be written with an understanding of the interests, needs, and capacities of boys of the eighth- and ninth-grade age levels. A college text revised for high-school use is not likely to fill this requirement. As a corollary, it should be prepared for student use at a particular age level and for a particular set of objectives, rather than for any situation where mechanical drawing may chance to be offered. Second, it should emphasize information and appreciation, as well as manipulative technique. Third, it should not presuppose succeeding advanced courses of a specialized nature by more than a small percentage of the groups. Fourth, it should emphasize informational materials not only about drawing, but also about related topics concerning industrial practices, materials, and machines. The guidance function should be directly recognized through information about related occupations. Fifth, the problems should, on the whole, be selected from real situations, and the real functions and values of the things drawn made apparent to the student before he begins work. A limited proportion of abstract exercises may be used if their value is made apparent to the student and application is made soon after.

The following paragraphs attempt to express what this book is, the functions it is designed to achieve, and the means provided for this end.

Situation for Which This Book is Intended

It is designed for the eighth or ninth grade, the ninth preferred. The first few lessons may be used in the seventh grade for a two- or three-weeks' course in drawing and drawing interpretation preceding entrance

upon actual shopwork. The materials of the text have been thoroughly tried out in the ninth grade.

An eighteen- or twenty-weeks' course is suggested. However, the material is sufficiently flexible to permit a rapid survey course of nine or ten weeks or a more intensive one of thirty-six or forty weeks.

Special Aims of This Course

1. To provide exploratory contacts with, and information about, a wide variety of drafting occupations and occupations depending on drafting.
2. To teach a variety of interesting and useful facts about industrial organization, methods, machines, and materials.
3. To teach certain *generally usable* skills in the making of simple mechanical drawings and in free-hand lettering.
4. To develop the ability to interpret working drawings.
5. To develop an appreciation of the interrelationships among industries, through drawing, the universal language thereof.
6. To develop the ability and the habit of using drawing as a tool in working out and planning matters of a mechanical nature.

Features of This Book

These are designed to achieve the special aims or functions set forth above and to assist in the accomplishment of the general functions* of the junior high school.

1. The course is arranged in lesson units.
2. Recognition of individual differences is given through provision for ability grouping or completely individualized instruction. It is especially adaptable to methods of individualized instruction.
3. An unusual number of problems of graduated difficulty is provided. All of these have been tried out on high-school boys, who have demonstrated their ability to do from forty to sixty pencil plates in eighteen weeks of five 60-minute periods each.
4. Information (technical, related, and occupational) is given a place of importance equal to that of the drawings.
5. The guidance function is emphasized in the informational parts of the text as well as in the drawing activities themselves.
6. The content is drawn from many situations, making it a general course in technical mechanical drawing.
7. Flexibility is a feature to accommodate courses of varying lengths.
8. The problems are selected wherever practicable to appeal to boys of the 13- to 16-year age levels.
9. Testing levels and materials are suggested in the text.

*Koos: *The Junior High School,* p. 17, Table 1.

10. Lettering instruction and practice are incorporated in the daily lessons.

11. The detailed organization should relieve the instructor of the necessity for building a course, searching for problems, working out assignments, and the like. This should provide him with time to give individual guidance, to make supplementary talks, to gather models and illustrative materials, to grade and check drawings, to score tests, and to attend to such other matters as are more purely *teaching* activities rather than analysis and organizing activities.

12. A section is addressed to the teacher, giving directions and suggestions for the use of the text.

To summarize, *this book provides a flexible course in general mechanical drawing planned specifically to meet the needs of boys of the junior-high-school-age levels.* It is based upon the objectives of industrial arts conceived as a fundamental part of a junior-high-school program.

The organization of the book in lesson units, emphasizing information as well as manipulation, is designed to provide for a systematic method of instruction. Individual differences are recognized by providing at least three levels of difficulty in each lesson. Each of the three distinct drawings in each lesson can be further varied in difficulty by changes in the mode of assignment.

THE AUTHORS

SUGGESTIONS TO THE TEACHER

The following suggestions regarding the adaptations of this text to local situations are offered with the hope that they will encourage intelligent use of, rather than slavish conformance to, the present arrangement. Some explanation of the special innovations used in the book also seems desirable.

The Typical Lesson Unit. The book is made up of 51 lesson units. With the exception of five which are wholly informational, each lesson consists of two parts: a drawing to be made, and certain informational material to be studied. These lessons are not of uniform length. They will require from 30 to 180 minutes each, of an average student's time.

Purpose. The statements under this section are intended to give the pupils a consciousness of the objectives and the value of the lesson. Every effort should be made through questions, suggestions, and environment (in the form of models, drawings, bulletin-board materials, etc.) to make the teacher's purpose the student's purpose as well. Only an interested and purposeful learner can achieve success.

General Information. This section should be read by each student and discussed in class. Practical limitations of space have made it necessary to cut this material to a minimum. Hence, it is urged that the teacher constantly supplement the text with short talks, library references, visits to industrial establishments, models, bulletin-board displays of pictures and drawings, and so forth.

For purposes of general industrial education and guidance within the field of industry, the authors feel that the informational aspects of the text are of equal importance with the training involved in making and reading drawings. A very brief class discussion of materials of this type should take place at the beginning of practically every class hour.

The Problem. Here is given a very general statement of the manipulative side of the assignment. It is expected that the teacher will usually supplement or change this section to suit the needs of his class and of the individuals in it. Although the authors have made an effort to provide variety in the assignments, the following ways of giving them are suggested for the teacher who wishes further change:

1. To copy the drawing as it is.
2. To use free-hand technique instead of mechanical, or vice versa.

3. To make a change in the drawing, such as in dimensions, shape, location of parts, etc.

4. To translate the drawing from one system to another, as from cabinet to orthographic.

5. To substitute a different drawing of a similar character.

6. To draw from a model or actual object.

7. To draw from written specifications.

8. To make a drawing of an original design.

Suggestions for Procedure. These suggestions are made very meager, with the belief that the student should learn to plan the details of his work for himself. It is suggested that, until the student shows some facility in organizing his layout, he be required to make a written plan to be checked by the instructor before he begins to draw. This would consist of a chronological list of the steps to be taken in making the particular drawing assigned.

The Drawings. There are three drawings in each lesson unit. Plate C in each case is the least difficult. It, or a drawing of similar difficulty, may be drawn by one sixth to one fourth of the class of least ability. Plate B is intended for the average group in the class, consisting of from one half to two thirds of the ordinary class. Plate A is the most difficult and is suggested for one sixth to one fourth of the class, which has high ability. These proportions apply only very roughly and may vary widely with different sizes of classes. The ratio of difficulty among the three drawings in each lesson is not constant either, which is another reason for varying the proportions. The ability of students may be arrived at tentatively after the first three or four lessons. The plates which a student himself does not draw should be studied. A few questions which require interpretation of the drawing will help and encourage such study.

In addition to providing for the individual differences in pupil ability, the three drawings in each lesson serve as useful teaching devices for purposes of generalization.

Lettering. It is suggested that no actual lettering be done by the pupils until Lesson 11, and that thereafter they be required to practice five minutes at the opening of each class period until an acceptable standard has been achieved. A standardized lettering scale should be the measure of achievement. After the first two weeks of lettering instruction, the practice may be done outside of class at the option of the instructor.

Tests. Because of the objective character of drawing, teachers frequently neglect to make use of tests as a means for measuring student-achievement. However, there can be no argument as to their value as measuring instruments, teaching devices, and diagnostic aids. This text

indicates six testing levels, and provides suggestive test items for each. These should not be used for purposes of measurement, however, because student access to them before the testing period would invalidate the results. On the other hand, they should be of value for purposes of diagnosis of student weaknesses, and of study and review. They should also be suggestive to the teacher in the construction of more comprehensive tests.

Grading Student Work. A grade should be given on each drawing, each written assignment, weekly estimates of oral recitation and discussion, and on each test. A cumulative point system of grading is suggested instead of letter grades. These may be translated periodically into letter grades for purposes of the school records. Any arbitrary assignment of points which will encourage increased quality and quantity of work will be satisfactory.

A class progress chart may be displayed in the room so that each student may know at all times how he rates in comparison with his fellows.

Making Adaptations of Content to Courses of Various Lengths

Introductory courses in general mechanical drawing are offered in courses varying in length from 9 to 36 weeks. This book is adaptable to all of these time allotments. It is important in this connection to keep in mind the general character of the course, and to see the need for making adjustments to time limits in such a way that the lessons selected will be representative of the entire subject. However, the course may be further thinned out or enriched, as the case may require, by reducing or increasing the assigned requirement in either the informational or manipulative phases of work, or both, in each lesson.

One of the most common faults in mechanical-drawing courses is that the minimum requirement is so low that students are permitted to waste time. It is, therefore, urged in the interest of better general training and of more representative exploratory experience that every effort be used to secure a speed of student work which will result in a real appreciation of the draftsman's job and the development of desirable habits.

THE AUTHORS

TABLE OF CONTENTS

Information Topic and Plates

LESSON PAGE

Foreword v
Suggestions to the Teacher viii
Choosing an Occupation 1
1. Drawings in Modern Industry 5

ORTHOGRAPHIC AND INSTRUMENTAL DRAWING

2. Drawing Equipment and Supplies 7
Plates 2C, B, and A—Straight Lining
3. Circles and Tangents 12
Plates 3C, B, and A—Curved Lines
4. Orthographic Drawing 15
Plates 4C, B, and A—Problems
5. Conventional Lines 18
Plates 5C, B, and A—Problems
6. Choice of Views 22
Plates 6C, B, and A—Problems
Supplementary Plate 6—Missing-line Test
7. Curves 25
Plates 7C, B, and A—Problems
Suggestive Test 1 28
Plates T1 and T2—Test Problems 29

PICTORIAL MECHANICAL DRAWING

8. General Principles of Perspective Drawing 30
Plates 8C, B, and A—Parallel and Angular Perspective
9. Oblique and Cabinet Drawing 33
Plates 9C, B, and A—Straight and Curved Lines
10. Isometric Drawing 36
Plates 10C, B, and A—Straight and Curved Lines

LETTERING

11. The Draftsman's Need for Lettering 39
Origin and Development of Letters. Examples of Typical Alphabets. Gothic Alphabet. Suggestions on Lettering. Practice Copy for Lettering.

LESSON PAGE

FREE-HAND SKETCHING

12. Uses, Materials, and Methods of Free-Hand Technical Sketching 44
Plates 12C, B, and A—Free-Hand Lining Exercises

MACHINE DRAWING

13. The Work of the Machine Draftsman 48
Plates 13C, B, and A—Free-Hand Sketches of Machine Parts
14. Specialized Workers in Machine Drafting Rooms 52
Plates 14C, B, and A—Link and Cranks
15. How Castings Are Made 56
Bearings and Bushings
Sections
Plates 15C, B, and A—Shaft Support; Gland; Shaft Coupling
16. Dimensioning 60
Plates 16A and 16B—Methods of Dimensioning
17. Pulleys and Belts 63
Plates 17C, B, and A—Pulleys and Handwheel
18. Auxiliary Views 67
Plates 18C, B, and A—Guides and Brace
19. Large Objects on Small Sheets 70
Plates 19C, B, and A—Shaft; Cylinder Head; Double Crank
Geometric Constructions 73
Suggestive Test 2 75
20. Standard and Interchangeable Machine Parts 76
Plates 20C, B, and A—Bolts; Threads
21. Gears 80
Plates 21C, B, and A—Gears
22. Cams and Cam Motion 84
Use of Notes in Drawings
Abbreviations
Plates 22C, B, and A—Eccentric and Cams
23. Forging and Heat Treatment of Iron and Steel 88
Machine-Shop Practice
Plates 23C, B, and A—Ring; Gasket; Guide
Dimension Schedules 92
24. Inking, Tracing, and Blue Printing 93
25. Boat and Marine Drawing 96
Plates 25C, B, and A—Rudder Brace; Oarlock Socket; Boat
26. Airplanes and Airplane Drawing 99
Plates 26C, B, and A—Gas-Tank Support; Wiring and Fitting
Wing Rib
27. Patent-Office Drawing 102
Plate 27—Patent Drawing of Wrench
Suggestive Test 3 105

LESSON PAGE

SURFACE DEVELOPMENT AND SHEET-METAL DRAWING

28. Surface Development in Pattern Drafting 106
Plates 28C, B, and A—Sheet-Metal Boxes; Plane Surfaces
29. Sheet-Metal Work 110
Plates 29C, B, and A—Pyramid; Cylinder; Cone
30. Sheet-Metal-Shop Practice 113
Plates 30C, B, and A—Box; Elbows

STRUCTURAL-STEEL DRAWING

31. Use of Structural Steel 116
Plates 31C, B, and A—Rivets; Steel Shapes; Columns

REINFORCED CONCRETE

32. Nature and Use of Reinforced Concrete 120
Plates 32C, B, and A—Flower Pot; Garden Seat; Garden Pool
Suggestive Test 4 124

PRINCIPLES OF DESIGN

33. Fundamentals of Design 125

FURNITURE DRAWING

34. Designing and Manufacturing of Furniture 128
Plates 34C, B, and A—Details of Table Joints; Footstool

ARCHITECTURAL DRAWING

35. Architecture and the Architect 133
36. Types of Domestic Architecture 138
37. Floor Plans 144
Plates 37C, B, and A—Playhouse; Shack; Scout Cabin
38. Elements of Frame-House Construction 148
Plates 38C, B, and A—Cornice; Sill; Section of Window
Supplementary Details
39. Standard Moldings and Millwork 152
Elevations
Plates 39C, B, and A—Shack; Playhouse; Scout Cabin
40. How to Build and Own a Home 156
41. Ornamental Metal Products 159
Plates 41C, B, and A—Street Sign; Grill; Chimney Anchor
42. Masonry Construction 162
Plates 42C, B, and A—Bonds; Arch; Window
43. The Work of a Landscape Architect 165
Plates 43C, B, and A—Landscapes of Garden and Lots
Suggestive Test 5 168

LESSON PAGE

Map Drawing

44. Maps and Map Drawing 169
Plates 44C, B, and A—Maps of City Blocks
45. The Civil Engineer and the Topographical Draftsman 172
Plates 45C, B, and A—Maps of City Districts
46. Conventional Topographic Symbols 175
Plates 46C, B, and A—Maps of Rural Districts
47. Contour Maps and Profiles 178
Plates 47C, B, and A—Contour Maps

Electrical Drafting

48. Electrical Engineering 181
Plates 48C, B, and A—Bell Circuit; Symbols
49. Radio Engineering 184
Plates 49C, B, and A—Radio Hook-ups and Symbols

Statistical Charts, Graphs, and Diagrams

50. Use of Diagrams and Graphs 187
Plates 50C, B, and A—Pie Diagram; Bar Graphs
51. Use of Line Graphs 190
Plates 51C, B, and A—Line Graphs
Suggestive Test 6 192
Final Examination 192

General Mechanical Drawing

CHOOSING AN OCCUPATION

John Williams sat at his table working more or less diligently upon his assignment for the next day's English class. His teacher had attempted to interest him in the Autobiography of Benjamin Franklin. He felt no special interest in reading what Franklin had to say about his own life, but since John was a good student and knowing that he must satisfy the requirements of the day's work in English, he now found himself reading a rather musty, forbidding-looking volume.

Much to his surprise, John found himself becoming intensely interested. Ben Franklin became a living boy again. From behind the pages of the old book he was expressing the same thoughts and feelings which John himself had been experiencing.

Suddenly John stopped, turned back a page and reread a paragraph. It seemed to impress him. He raised his eyes from the printed page, rested his chin in a cupped hand, and stared thoughtfully into the corner of the room. After an interval he turned his head toward the living room where his father sat reading his evening newspaper. "Dad," he called.

Mr. Williams rustled his paper a bit impatiently but answered, "Yes, son, what is it?"

"Listen to what it says here in my book," said John, as he began to read.

"He therefore sometimes took me to walk with him, and see joiners, bricklayers, turners, braziers, etc., at their work, that he might observe my inclination, and endeavor to fix it on some trade or other. . . . It has ever since been a pleasure to me to see good workmen handle their tools, and it has been useful to me, having learned so much by it as to be able to do little jobs myself in my house when a workman could not readily be got, and to construct little machines for my experiments."

"Why don't fathers do that nowadays," asked John, as he finished reading. "You know you told me just the other day that I would have to go to work when I am 18. But how am I to know what kind of work will be best for me? Why don't we take a trip some afternoon like Ben Franklin and his father did? Come on, Dad, please. It would be a lot of fun, too."

Mr. Williams looked at his son in mild surprise and with a suggestion of amusement in his eyes. "We have come a long way since Franklin and his father took those little trips, John. Do you know that the United

States census now lists over 3,000 occupations? Why, the plant where I work has over 300 different payroll jobs. I'm afraid, John, that we would find the afternoon a bit short for a trip like the one you suggest."

John's father had forgotten his paper which lay in a rumpled pile on the floor. He looked quizzically at his son for a moment and said, "I am glad you have raised the question of your future work, though, John. I've been thinking of it some myself."

He then went on to explain to John that because of extreme specialization in all fields of work, there are more and more new types of work developing every day; that some trades in which thousands of men were employed a generation ago no longer exist, and that jobs in industry are often so specialized that the men who work at them would not be able to find other jobs just like them any place else in the world.

In the meantime John's face took on a mildly worried look. Finally he interrupted his father's discourse which was getting a little beyond his depth. "But, Dad," he said, "if what you say is true, what is the use of my going through the high school? By the time I get through the stuff they teach there, it probably will no longer be used anyway. And besides, if there are so many jobs, they certainly can't teach them all in school. How would the boys know which course to take anyway, I'm sure I don't."

Mr. Williams shook his head and replied, "The truth of the matter is, John, that I have been so busy at my own job that I know very little about opportunities in other lines, and the schools have changed so since my day that I know little about what they are doing. They do tell me, though, that there is a young man down at the high school called a vocational-guidance counselor. My suggestion would be that you go to see him. Perhaps he can help us out. It's time to turn in now, but go and see this man tomorrow, John, and let me know what he tells you."

John found Mr. Gordon, the counselor, the next day. He was a kindly man and saw at once that John's difficulties were little different from those of the hundreds of other boys he had occasion to interview. After the usual preliminary questions, Mr. Gordon showed John the diagram seen in Figure 1, and explained it to him as follows:

One's choice of an occupation is a three-sided proposition. The first question one naturally asks is, "What interests me?" The best way to discover this is to experience as many kinds of work as possible. The courses in junior high school, especially those in shopwork,

Fig. 1

drawing, art, junior business, etc., are designed largely for this purpose. Work after school, on Saturdays, and in the summer is another means of discovering one's interests through experience. To read about occupations is still another method.

To know one's interests is not enough, however. For example, a boy might be interested in becoming a professional prize fighter, but if he lacks good health and physical strength, it is apparent that he *lacks capacity*. Similarly, one might be interested in the work of a civil engineer, but if he does not possess considerable mathematical ability it would be a waste of effort to attempt to become an engineer. It is therefore necessary that a young person interested in selecting an occupation should study himself, in relation to his interests, to discover what special abilities or disabilities he may or may not possess.

Interest and *capacity* have to do with one's own character and personality. A knowledge of these is of great importance, but still one side of the triangle remains. The question which presents itself is, "What *opportunities* exist in the work of the world to apply to best advantage my particular combination of interests and capacities?" To illustrate, one might have great interest and ability in blowing soap bubbles, but little opportunity exists for making a living by such an occupation. There are many occupations which were important ten years ago, which have practically disappeared, and other new ones have sprung up overnight as the result of new mechanical inventions. It is, therefore, necessary that one's interests and capacities be directed toward some activity for which the world is now willing to pay a price.

To choose an occupation wisely, ~~then,~~ requires not only a knowledge of one's own interests and capacities, but also a fund of information about the opportunities which exist in a large number of important lines of work.

After listening with much interest to Mr. Gordon's explanation, John said, "Yes, Mr. Gordon, all that sounds very sensible, but just how does it help me? I am in the ninth grade and have only two years after this before I must quit school and go to work. What shall I do with my remaining years in school, and how shall I know which occupation is best to enter?"

"We shall help you all we can, John, but the final decision must always rest with you," replied Mr. Gordon. "Before attempting to give you any suggestions, however, let me ask you some questions."

Mr. Gordon's questioning revealed the fact that John was interested in some type of mechanical work, but that he could not decide upon the particular specialty. Furthermore, the school records showed that he possessed more than average ability in these fields. He was advised, there-

fore, that there seemed to be no good reason why he should not learn a mechanical trade. It was suggested, however, that he wait a year before making a choice, and in the meantime find out everything possible about the opportunities which existed in this group of occupations.

Several school courses were also suggested to him. Among these was one called "An Exploratory Course in General Mechanical Drawing." It was explained that, since mechanical drawing is basic to all mechanical industries, this course would give much valuable information about industry, and at the same time provide some skill in drawing which would be sure to prove valuable.

DRAWINGS IN MODERN INDUSTRY

Lesson 1. Information

We are living in an age when mechanical things are playing an ever-increasingly important part in our lives. Electrical power, gas and steam engines, and the many ingenious devices with which these are used have increased the amount of work done per man several hundredfold. In fact, if you compare yourself with a person who lived at the time Columbus discovered America, you will find that you have, in mechanical form, the equivalent of about three hundred slaves who work for you night and day and stand ready to serve your slightest wish.

Even more interesting to boys, about to start training for a lifework, is the fact that most of the real developments in mechanical fields have come within the past sixty or seventy years. This is made clearer if we compare the period of the entire recorded history of the human race to a 24-hour day; then the period (about thirty years) in which the telephone, automobile, airplane, electric lighting, and radio, etc., have come into common use would be less than ten minutes. It seems that we are only on the threshold of a period of great industrial and mechanical development. It is impossible to do more than guess at the opportunities which lie ahead.

This seemingly magical change has been brought about by the work of scientists who discover new facts and principles, and by engineers, draftsmen, and mechanics who design, plan, and make the thousands of devices which make practical use of the scientific principles discovered in laboratories.

In the lessons which follow, you will be given an opportunity to sample a few of the many kinds of work done and information needed by people engaged in technical planning. Such planning is done by means of technical or mechanical drawing.

Mechanical drawing has been said to be the language of industry; that is, it is the means by which mechanical ideas are worked out, recorded, and transmitted to others. Like any other language, it may be written (drawn) and read. It has the advantage of being a universal language; in other words, a drawing made in one country is readily understood in any other. It is possible to learn to read drawings without being able to make them. In fact, most of the people who make use of drawings are required to do much more reading than making of drawings.

A man whose business it is to make drawings is called a draftsman. Those called upon to read them may be other draftsmen, foremen, workmen, inspectors, lawyers, scientists, business men, or home owners. In fact, almost anyone usually has more or less frequent occasion to interpret or read mechanical drawings of some kind.

One can hardly mention an industry today in which drawing does not play an important part. We all know, more or less, of its many uses in building design and construction and also its great importance in the design and manufacture of machinery. Drawing also is used widely by such people as surveyors, mining engineers, road builders, soldiers, telephone men, electricians, landscape architects, salesmen, makers of electric-light fixtures, manufacturers of ornamental iron and the like, park board employees, patent-office employees, statisticians, teachers, and scientists. The importance of drawing in the industrial world today is made clear when one stops to think that every bridge, building, automobile, tool, or piece of jewelry which we see, was first worked out on pieces of paper by draftsmen.

The increasing use of semiautomatic machines in present-day industry, and the tendency to employ workmen with little experience or skill to do simple specialized jobs, has taken away from the workman much of the responsibility formerly placed upon him. Frequently, the only men in a factory who understand the complete process of manufacturing a given product are the foremen and the draftsmen. This condition makes it necessary for the draftsmen to have a great deal of information about the things they draw. It also makes it necessary for them to give much greater attention to minor details than would be required if highly skilled workmen were to use the drawings. Furthermore, it is quite common to make several thousand pieces from one drawing.

The draftsman is a key man in industry today, and if he is capable and willing to work and study, his chances for advancement are very good indeed. Many nationally known manufacturers began their careers as draftsmen.

Suggested Questions and Topics for Class Discussion

1. What is the meaning of the word "industry" as used in this lesson?
2. What is meant by "mechanical power"?
3. What is the difference between a scientist and an engineer?
4. Compare mechanical drawing as a language with the English language.
5. Name several occupations in which drawing is seldom if ever used. Can you point out an object in the room in the manufacture of which drawing has not either a direct or indirect use?

Note: The next eleven lessons attempt to give the student the first rules of the "grammar" of the drawing language. Learn them well, as they are the foundation for the more interesting lessons which follow.

ORTHOGRAPHIC AND INSTRUMENTAL DRAWING

Lesson 2

I. *Purpose*

1. To learn about the equipment and supplies used by draftsmen.
2. To learn the correct method of drawing straight lines with pencil, T square, and triangles.

II. *General Information: Drawing Equipment and Supplies*

A mechanical draftsman is a very high-grade mechanic. Like all mechanics, he must have certain tools or instruments, as well as materials with which to work. The most important of these are described as follows:

The drawing board should be made of a soft, close-grained wood into which thumb tacks may be easily pressed. (Plate 1.) White pine or bass-

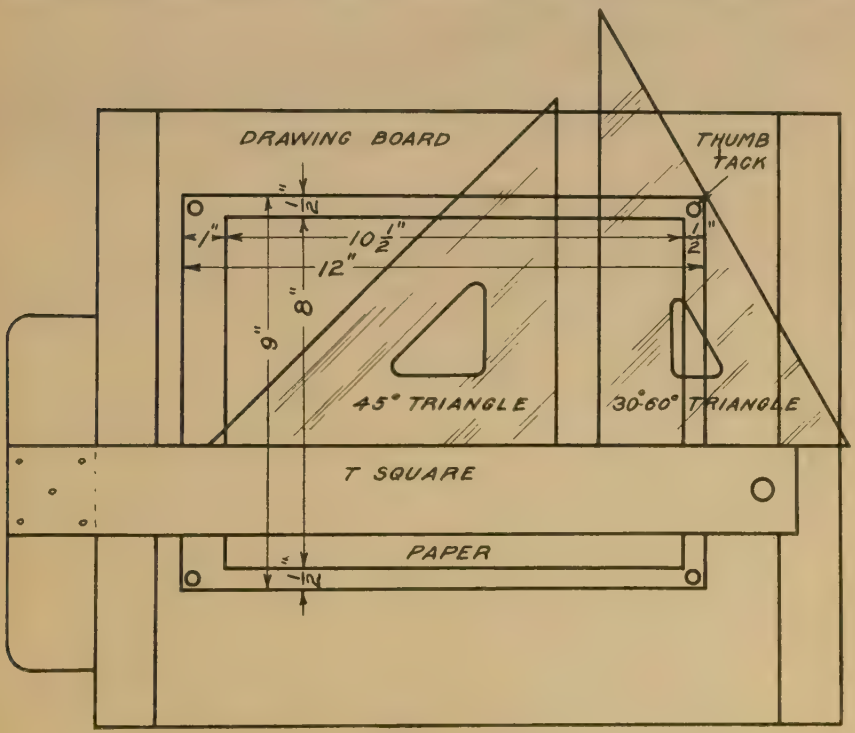


Plate 1

wood are suitable. One edge of the board must be perfectly straight, and the surface true and smooth. Sizes vary, depending upon the sizes of drawings to be made. A suitable size for the work of this course is 15″ x 18″.

The T square should be made of hard wood. (Fig. 2.) The head should be fixed securely to the blade. The blade should be perfectly straight. The more expensive T squares have blades with transparent edges.

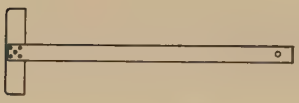


Fig. 2. T square

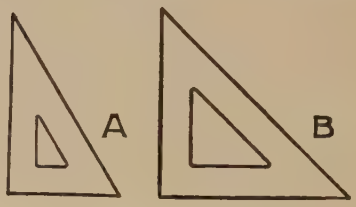


Fig. 3. A, 30–60° triangle
B, 45° triangle

Triangles should be of transparent celluloid. (Fig. 3.) Two are required for ordinary work. An 8″ 45° triangle and a 10″ 30–60° triangle are suitable.

Scales. An ordinary 12″ beveled-edged rule, divided into sixteenths of an inch, is widely used and is suitable for the work of this course. A triangular scale, made of boxwood, usually is used by draftsmen. (Fig. 4.) Besides the regular 12″ full-size scale, the triangular instrument provides several other scales of reduced sizes useful for different purposes. Architects, mechanical engineers, and civil engineers use scales with somewhat different graduations.

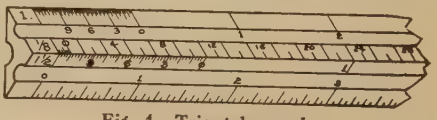


Fig. 4. Triangular scale

Drawing pencils are graded by letters from 6B (very soft), 5B, 4B, 3B, 2B, B, HB, F, H, 2H, 3H, 4H, to 9H (extremely hard). About a 4H or 5H pencil may be used for layout work, and when the drawing is not to be inked, a 2H should be used for darkening the lines. Accuracy requires that the pencil be kept sharp.

Fig. 5. Pencil Points

Ink. When drawings are inked, a special drawing ink should be used. Black is most common, although various colors are sometimes used for special purposes.

Erasers. For erasing pencil lines, a soft-rubber eraser should be used. Although it should rarely be necessary to erase ink lines, special ink erasers are available.

Paper. Drawing paper comes in many varieties. For our purpose three kinds should be mentioned. *Detail paper* is used for nearly all original drawings. It usually is about three times as heavy as ordinary writing paper, and has a firm surface which will stand considerable erasing. The surface is dull, never glossy. White or light buff are the most common colors. *Tracing paper* is strong, thin, and transparent, and is used for making tracings from which blue prints may be made. *Tracing cloth* is a fine fabric coated with gelatin or starch to make it transparent. It is used for making the final inked tracings of high-class drawings.

The set of instruments. Besides the items described above, every draftsman is equipped with a "set" of drawing instruments similar to that shown in Figure 6. Such sets vary from a very simple one containing a ruling pen and a combination compass and dividers, to elaborate sets of as many as ten or twelve pieces, made up of separate instruments for different purposes.

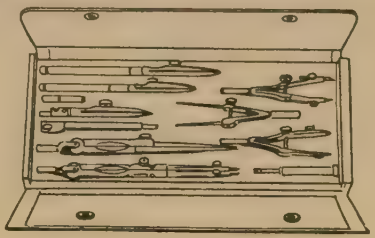


Fig. 6. Set of drawing instruments

The drafting room should be clean and well lighted. Light should come from the left and the front of the draftsman in such a way as to eliminate shadows on the drawing board. Drawing benches should be high enough to permit the draftsman to stand up and work. A high stool is then necessary to permit him to sit without adjusting the table height.

Miscellaneous equipment, consisting of filing cases, drawers, racks, blue-printing equipment, French curves, (Fig. 7), large drawing boards, etc., also is found in the commercial drafting room.

Fig. 7. French curve

Sources for further study:

French: *Engineering Drawing,* Chap. II.

Catalogs of drawing supply companies.

III. *The Problem*

To copy one of the drawings shown in Plates 2C, B, and A, paying particular attention to the correct uses of the board, thumb tacks, T

square, and triangles. Do not begin until your instructor has shown you how to handle these instruments. If you form bad habits at the beginning, it will be difficult to keep up with the class.

IV. *Suggestions for Procedure*

1. Fasten a 9″ x 12″ sheet of drawing paper to the board. Note Plate 1 for its proper location on the board. Adjust the paper so that its top edge is parallel with the T square, and fasten with four thumb tacks.

2. Lay out a standard sheet, divide it into six parts, and copy the drawing assigned. *Complete the layout, using very light lines.* Check carefully for errors, and darken the lines with a 2H pencil. Erase all unnecessary light layout lines. (Standard sheet shown in Plate 1.)

Do Not Copy Dimensions, Dimension Lines, or Titles on This or Any of the Following Drawings Until Instructed to Do So. Merely draw the lines indicated, and sign your name in the lower right-hand margin.

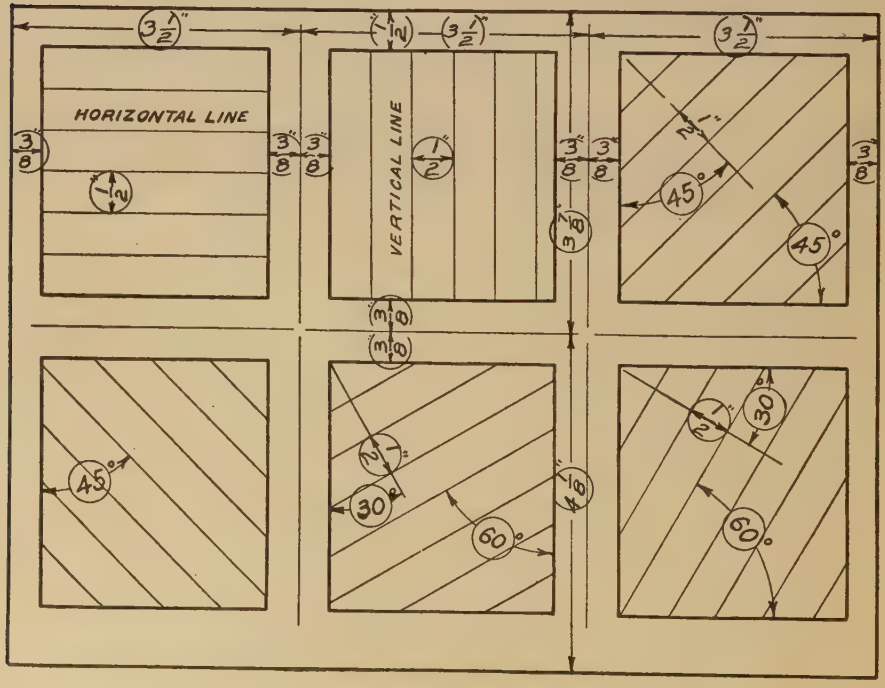


Plate 2C

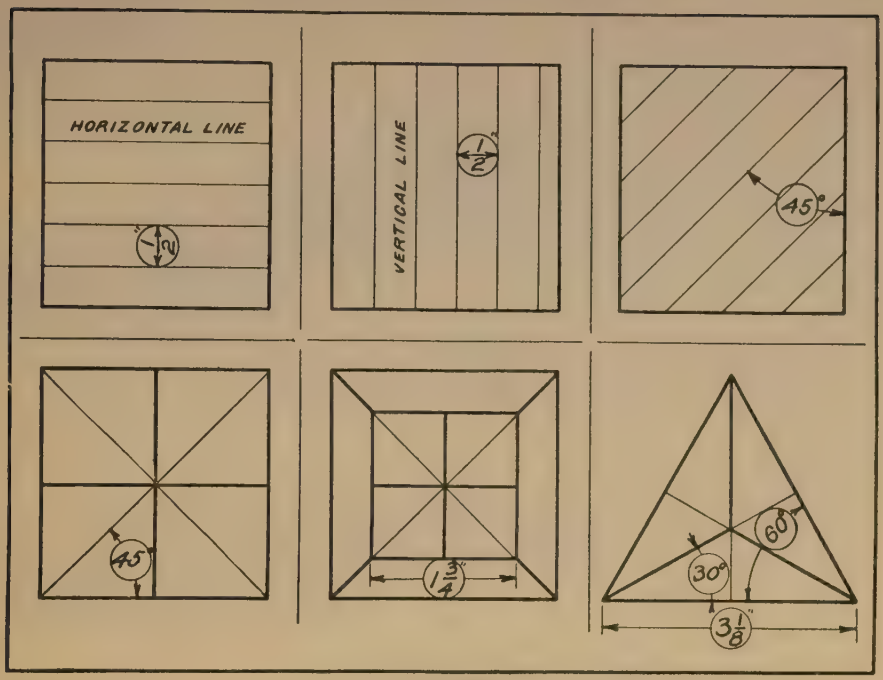


Plate 2B

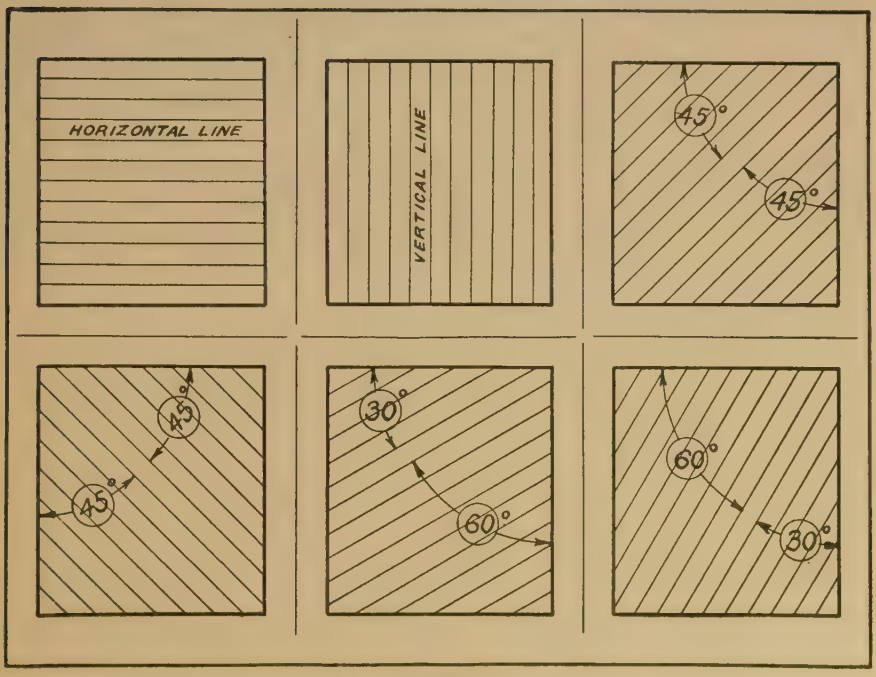


Plate 2A

Lesson 3

I. *Purpose*

1. To learn about circles and tangents.
2. To use the compass, draw center lines, and locate points of tangency.

II. *General Information: Circles and Tangents*

In the preceding lesson we learned how to draw various kinds of straight lines. Circles and arcs of circles are used extensively in mechanical drawing, alone and in connection with straight lines.

Fig. 8. Pencil compass used by a mechanical draftsman

Fig. 9. Pencil compass for school use

The instrument used for drawing circular lines is the compass. The type used by the mechanical draftsman is shown in Figure 8. For the work of this course, an ordinary school pencil compass will serve. (Fig. 9.)

Circles and arcs are located in drawings by means of their centers which are shown by crossed center lines. To draw a circle, set the compass points at a distance apart equal to one half the diameter of the circle (i.e., the radius). Insert the point of the compass carefully and lightly into the paper at the center of the circle. Hold the top of the compass between the thumb and finger, and revolve it in a clockwise direction.

A line is tangent to a circle when it touches the circumference but does not cross it. The point of tangency is the point at which the line touches the circle. The exact point of tangency may be found by drawing a radius at right angles to the tangent line.

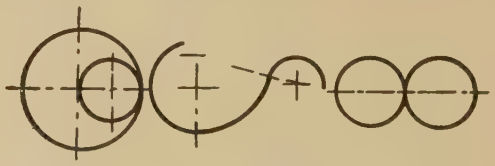


Fig. 10. Circles may be tangent to each other, either internally or externally. Two circles are tangent to each other on the line of centers

Sources for further study:

French: *Engineering Drawing,* Chap. II.

Sturtevant: *Supplementary Problems in Mechanical Drawing,* pp. 15–16.

III. *The Problem*

To copy one of the drawings shown in Plates 3C, B, and A, paying particular attention to the use of the compass.

IV. *Suggestions for Procedure*

1. Locate and draw center lines.
   a) Note that center lines are light lines made up of alternate long and short dashes.

2. Locate points of tangency exactly by drawing light lines through them.

3. When darkening the lines, draw circles first and straight lines second. To gain speed draw all the horizontal lines, then all the vertical lines, and then the slant lines.

4. In the lower left-hand drawing in Plates 3C, B, and A, the points of tangency between the sloping lines and the circles are found as follows: First, draw the arcs at the ends, then lay a triangle so that it just touches both circumferences. With a second triangle, draw a radius at right angles to the first triangle. This radius will pass through the circumference at the point of tangency.

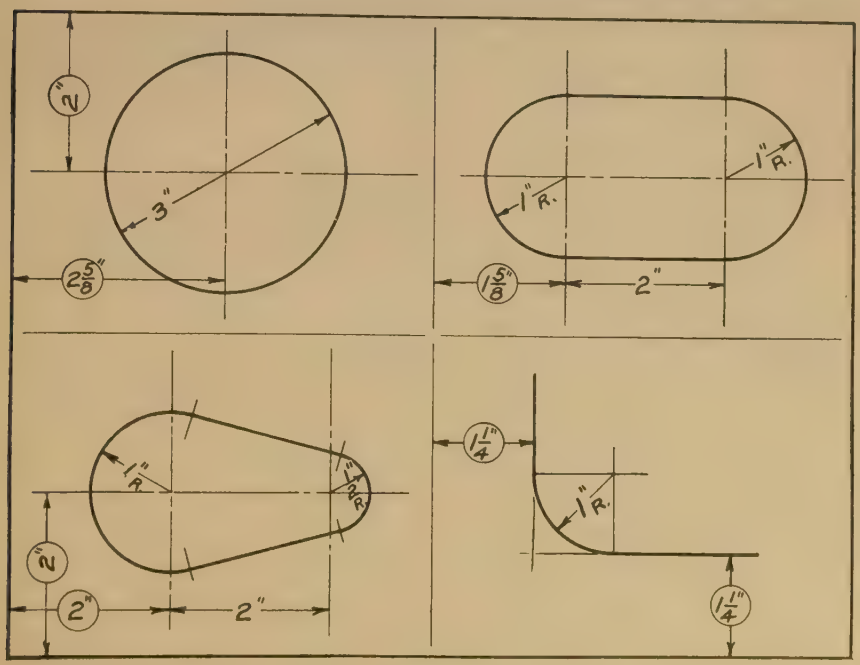


Plate 3C

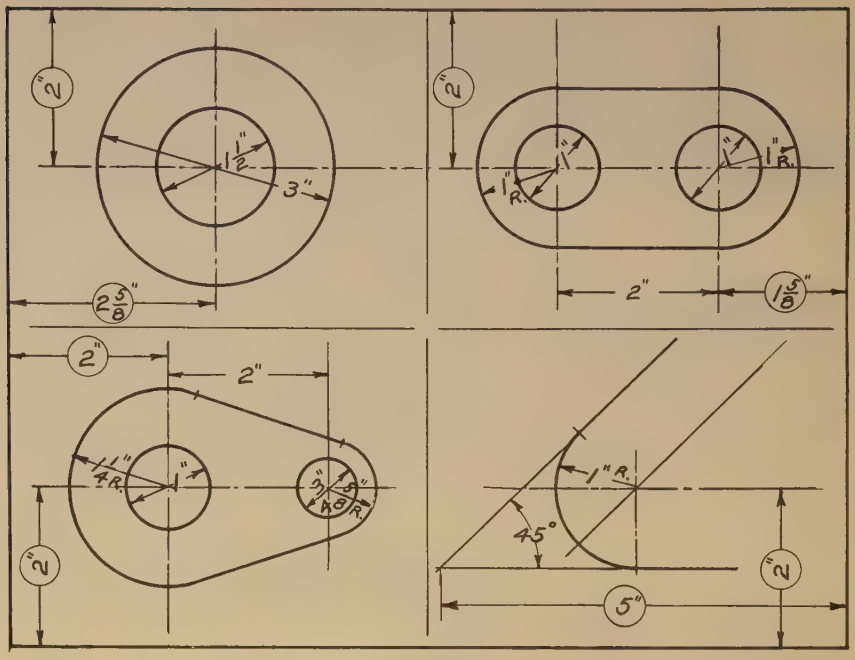


Plate 3B

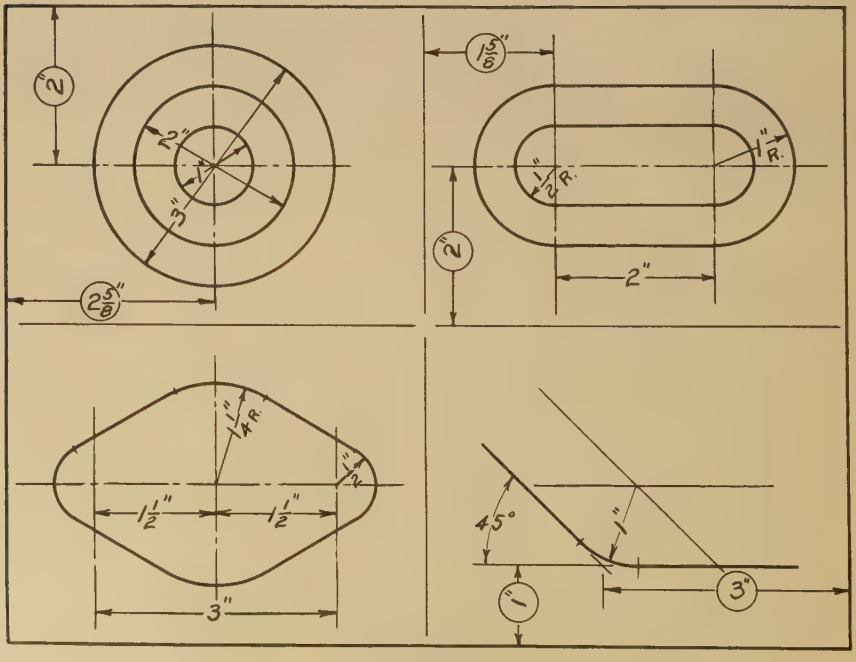


Plate 3A

Lesson 4

I. *Purpose*

1. To learn the underlying principle of orthographic drawing.
2. To apply this principle in a drawing of a simple rectangular object.

II. *General Information: Orthographic Drawing*

Mechanical drawings or working drawings usually are made according to the orthographic system. The name comes from the Greek words *"orthos,"* to write, and *"graphos,"* to draw. It means a "drawing language."

Mechanical drawings differ from pictorial drawings or pictures in that they show the object as it really is, instead of as it appears to the eye of the observer. By means of several views arranged in a definite relation to each other, it is possible to show clearly all parts of the object.

The arrangement of views must be learned. The top view is placed above the front view, the bottom view is placed below the front view. The right-end view is at the right of the front view and the left-end view is at the left of the front view. It seldom is necessary to draw all five views. Usually three views are enough, often two views are ample.

The front, top, and one of the end views are frequently drawn, and will be used in most of the drawings of this course.

The relation of views may be seen by a study of the accompanying drawings. Imagine the object placed in a glass box, and the different views drawn on the front, top, and end of the box. (Fig. 11.) If the top and end of the box are swung into the same plane with the front of the box or the vertical plane, the views will be correctly arranged.

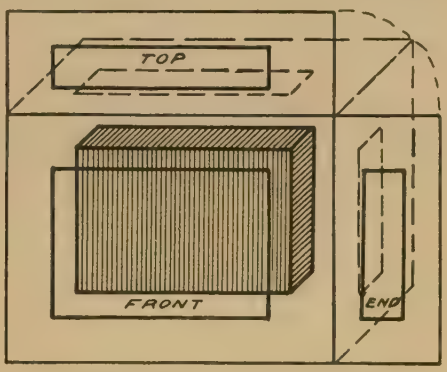


Fig. 11. Views projected to sides of a glass cage. When these sides are opened, the correct arrangement of views is obtained

In reading the drawing, these views will be thought of as the front, top, and end views.

The relation of views is as important as the relation of letters in a word. In their correct order, they have a definite meaning, but if the order is changed, they do not give the meaning intended.

Sources for further study:

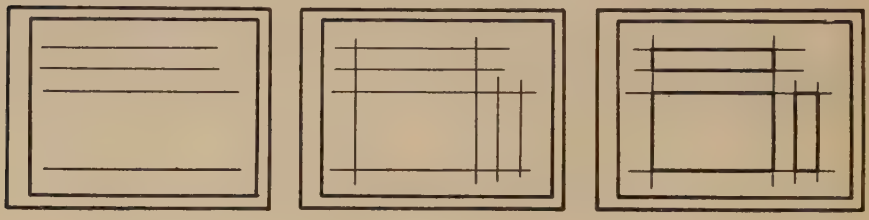
French: *Engineering Drawing,* Chap. VI.

III. *The Problem*

To copy the drawing assigned. (Plates 4C, B, and A.) Try to visualize how the object actually looks.

IV. *Suggestions for Procedure*

See the layout shown in Figure 12.



Step 1 Step 2 Step 3

Fig. 12. Steps in laying out views on a sheet

1. Use very light pencil lines (4H pencil), extending all lines nearly to the border.
2. Lay out the top, front, and end views.
3. Erase the light lines where they are not needed.
4. Darken the outlines with a firm line, using a 2H pencil.

Reminder: Do not put dimensions or titles on these drawings.

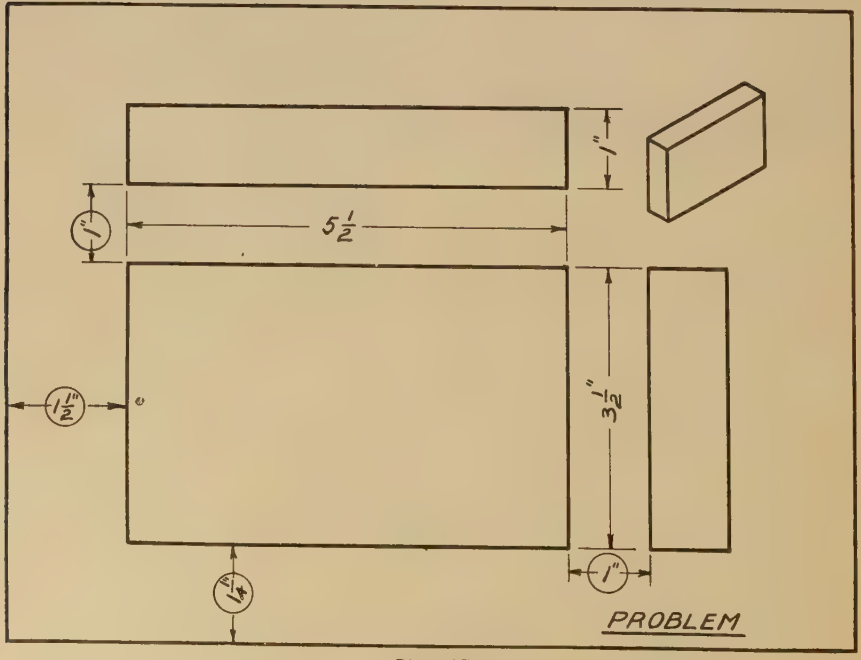


Plate 4C

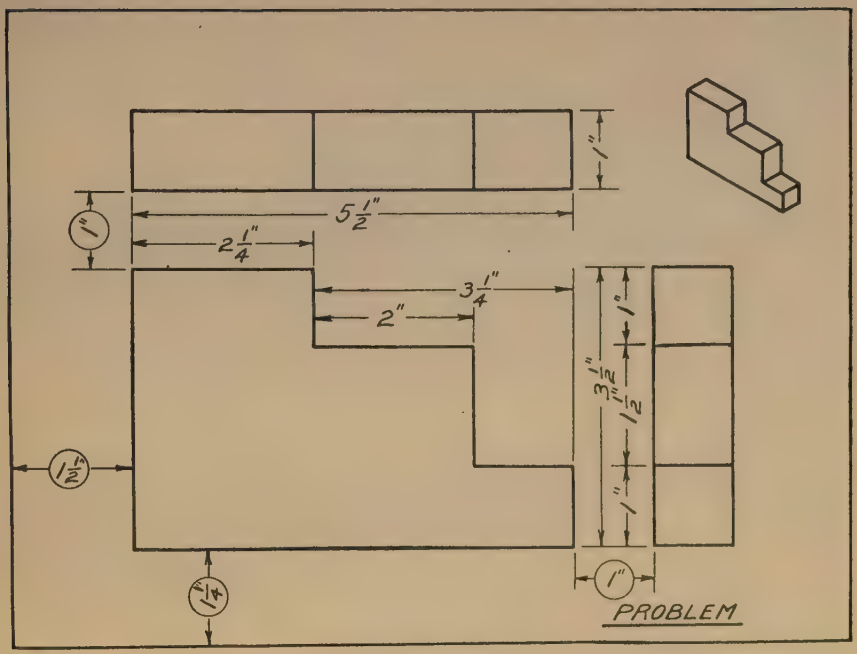


Plate 4B

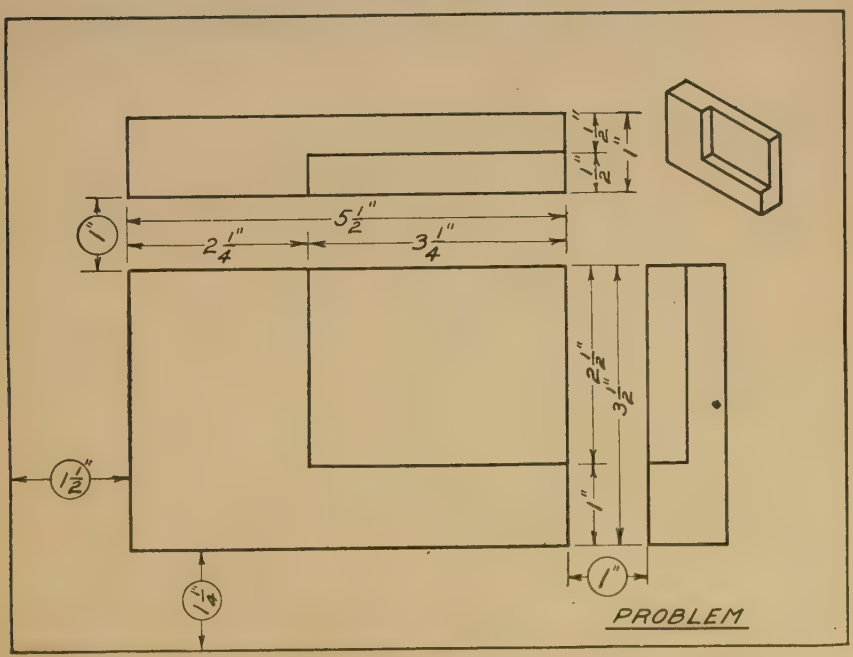


Plate 4A

Lesson 5

I. *Purpose*

1. To learn the alphabet of conventional lines.
2. To make use of the line representing the invisible outline in a simple drawing.

II. *General Information: Conventional Lines*

In order that drawings may be easily and quickly read, lines of different kinds are used to represent different things. The use of these conventional lines sometimes referred to as the "alphabet of lines," has been standardized by long use or custom.

Figure 13 shows the lines most commonly used. Other lines used for special purposes are not given here.

The distinction between any two of these lines should be so clear as to eliminate any possibility of confusion in reading. These distinctions are of two kinds, make-up and weight.

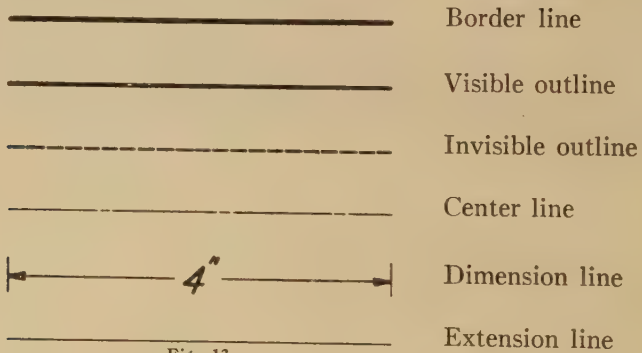


Fig. 13

The *border line* is a heavy black line used in making a border around a sheet.

The *visible outline* is a strong solid line used to show all visible edges and outlines of the object drawn. Formerly the border line was made heavier than the outline, but more recently the tendency is to make these two lines the same weight.

The *invisible outline* is a line used to show edges and surfaces which are hidden from view by other parts of the objects. This line is made up of short dashes usually about ⅛″ long, separated by 1/16″ spaces. The

length of these dashes may vary somewhat depending on the length of the line, longer dashes being used in longer lines. While this line is often referred to as a dotted line, it is not made up of a series of round dots. The weight of the invisible outline is slightly less than that of the visible outline.

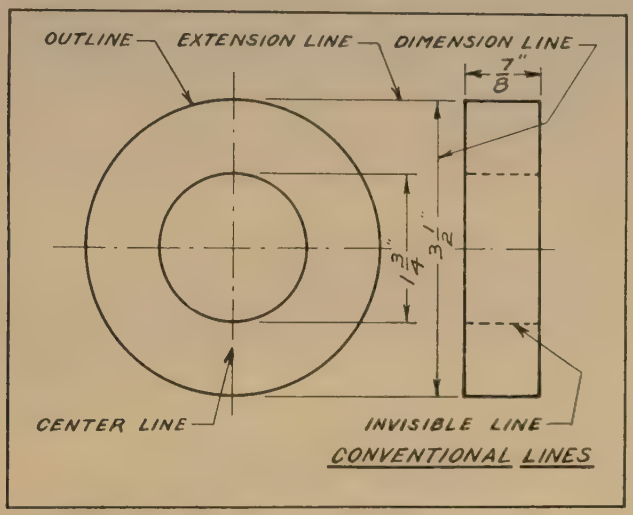


Fig. 14. A number of conventional lines are used on even the simplest drawings

The *center line* is used to indicate the center of an object, or to show the location of centers of circles and arcs. It is made up of alternate long and short dashes. The long dashes are usually about ½" long and the short ones ⅛". It is a very light-weight line, not over one half the weight of the visible outline. This line sometimes is called a "dot-and-dash" line.

Dimension lines are continuous lines broken in the middle to provide space for figures. Arrowheads are placed at the extremities to show the exact point between which the dimension reads.

Arrowheads are important. They should be about 3/16" long, 1/16" wide, and sharply pointed.

Extension lines, or witness lines, are light lines extending out from the object to assist in showing the exact limits of a dimension. They should never touch the object. A space of about ⅛" is usually left between them and the object.

Sources for further study:

French: *Engineering Drawing,* p. 27.

III. *The Problem*

To copy Plate 5C, or 5B, or make a three-view working drawing of the block shown in Plate 5A. Learn why the dotted lines are used.

IV. *Suggestions for Procedure*

1. Draw very light pencil lines (4H pencil), extending all lines nearly to the border.
2. Lay out the front, top, and end views.
3. Erase the light pencil lines where they are not needed.
4. Darken the outlines with a firm line, using a 2H pencil.

Note: The foregoing procedure will be carried out in all similar drawings in the following lessons.

5. In Plate 5A, draw the right-end view. How many dotted lines will there be in this view?

Questions

1. In Plate 5C, why is the line in the right-end view a dotted one?
2. In Plate 5B, in the top view, why is one of the inside lines dotted and the other solid?
3. In Figure 14, page 19, how many different kinds of lines are used? Name them.

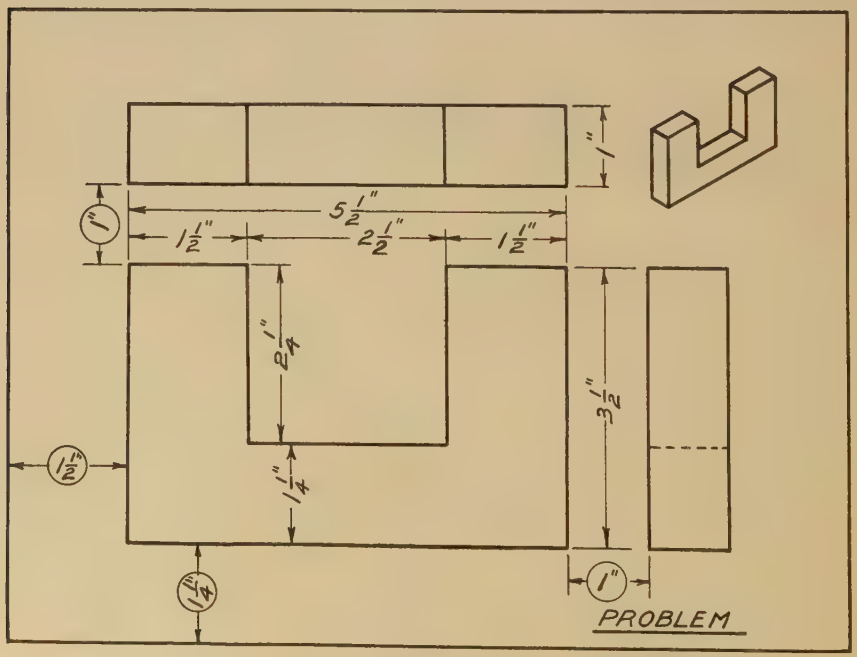


Plate 5C

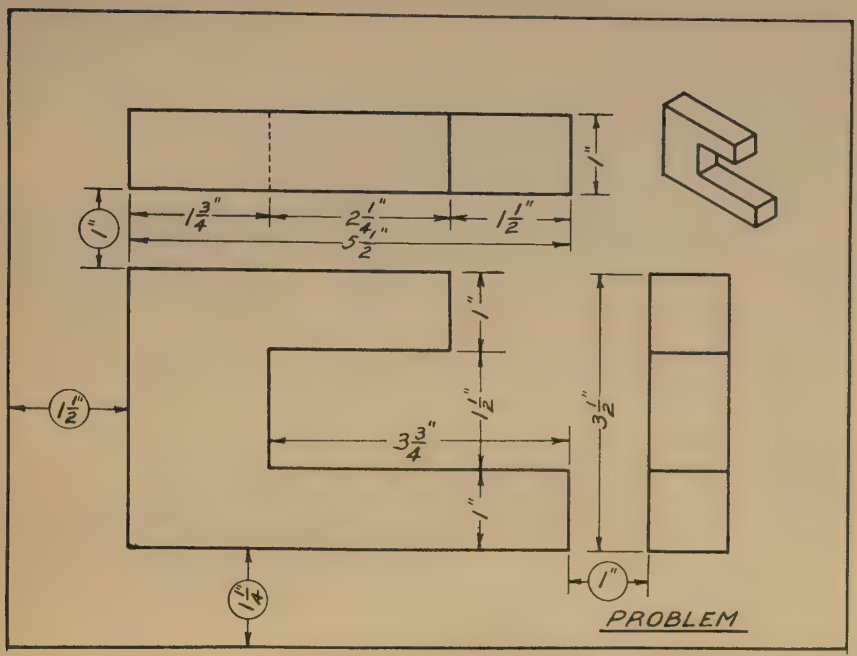


Plate 5B

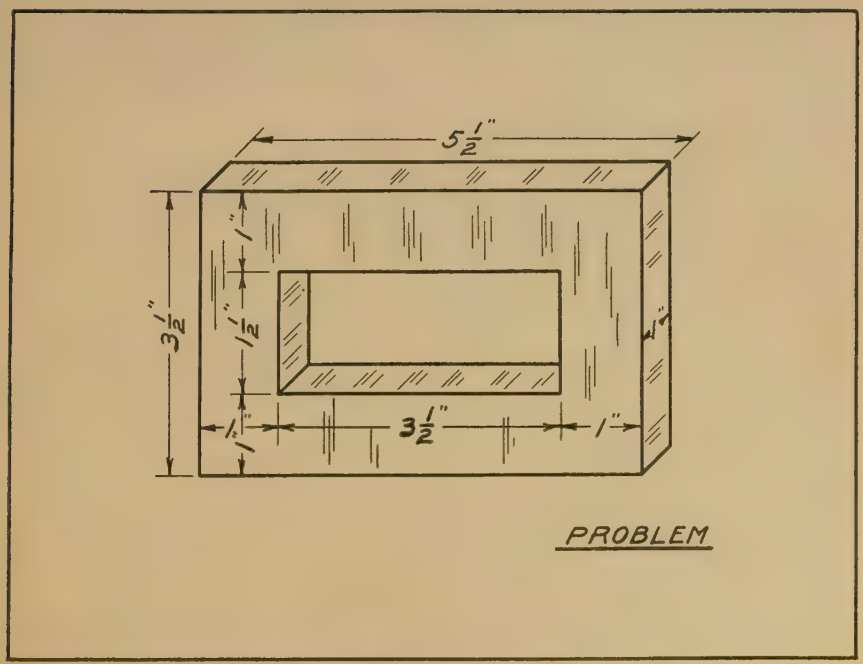


Plate 5A

Lesson 6

I. *Purpose*

1. To learn how to select the best views to draw.
2. To represent invisible lines falling directly behind visible lines, and to draw objects with slanting surfaces.

II. *General Information: Choice of Views*

Although it is possible to make almost any number of views of an object, it is best not to use more views than are necessary to make the drawing perfectly clear. Three views are commonly used; they are the front, top, and right-side views. There is no reason, however, why the left side should not be drawn instead of the right, if by so doing the drawing is made clearer through the use of fewer dotted lines, or if the outline shows more clearly from that side. For similar reasons, the back or bottom views, or other views at an angle with the main faces of the object, may be used. These sloping views are explained in Lesson 18.

In school courses in drawing, it is customary to use three views. This is not necessary, but it is good practice for the students. Most common objects can be shown fairly well by two views. In drawings of some objects, two of the three views would be exactly alike, as in the case of a tin can, spool, or rolling pin. In such cases, three views are never used.

In drawings of spherical objects, one view is enough. This is true in the case of thin objects of uniform thickness, as, for example, notebook covers, engine gaskets, and the like. A note is added to such drawings to indicate thickness.

Objects which stand in a certain position should be represented in that position in all views of a drawing. For example, a drawing of an ordinary chair would be confusing if it were represented lying on its side.

Note the selection and arrangement of views in the lessons which follow.

III. *The Problem*

Copy one of the accompanying drawings in Plates 6C and 6B, taking particular note of how an invisible edge is represented when it falls behind one which is visible. Note also how sloping surfaces in one view appear on the other views. In Plate 6A, make a three-view working drawing of the block shown.

IV. *Suggestions for Procedure*

1. Follow the same layout steps in this as in preceding lessons.
2. Try to see how quickly this drawing can be made. Do it in fifteen minutes or less if possible.

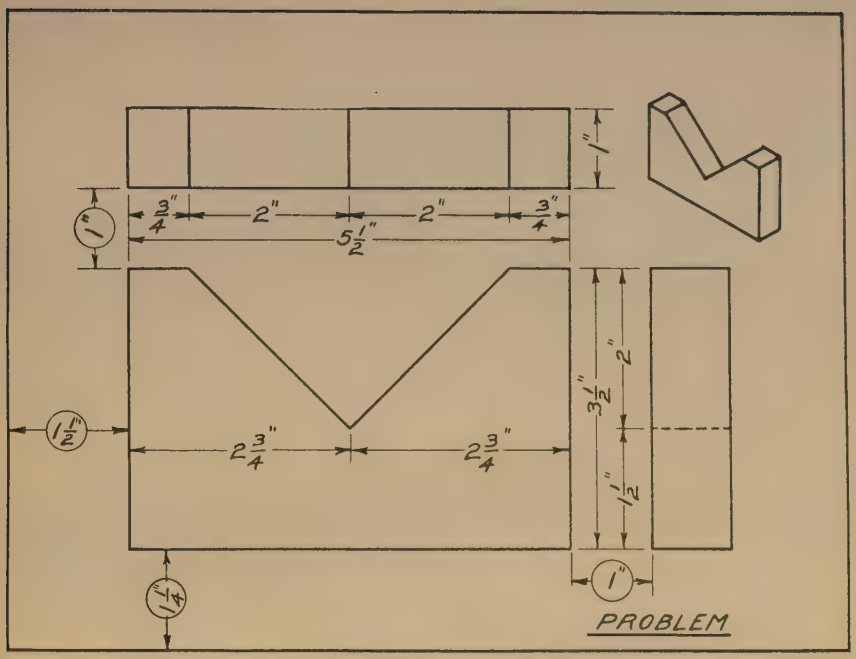


Plate 6C

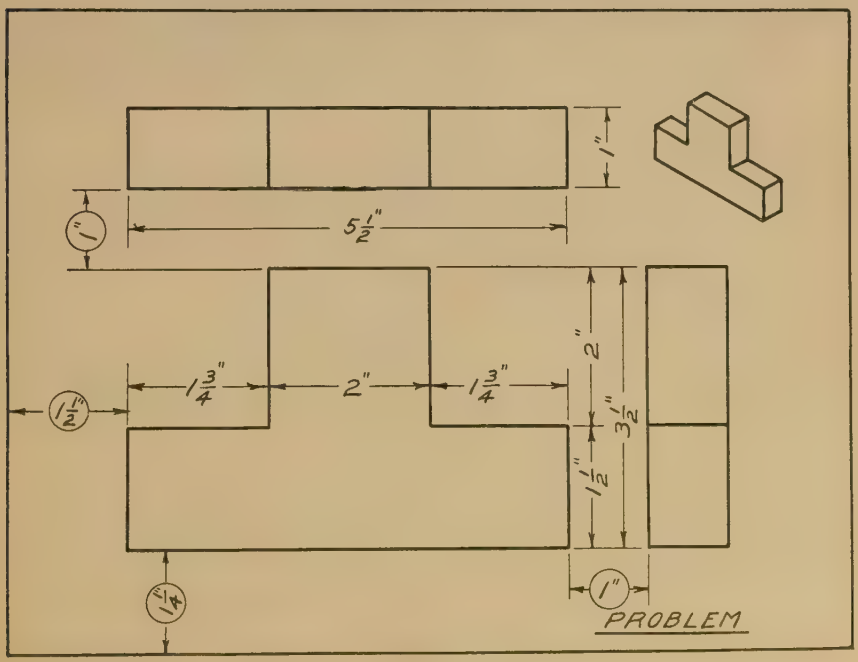


Plate 6A

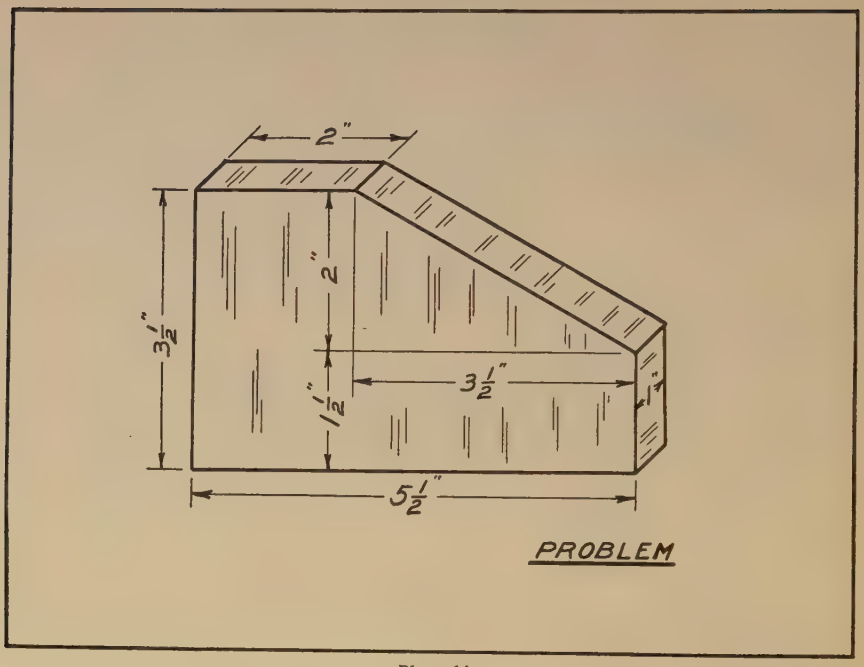
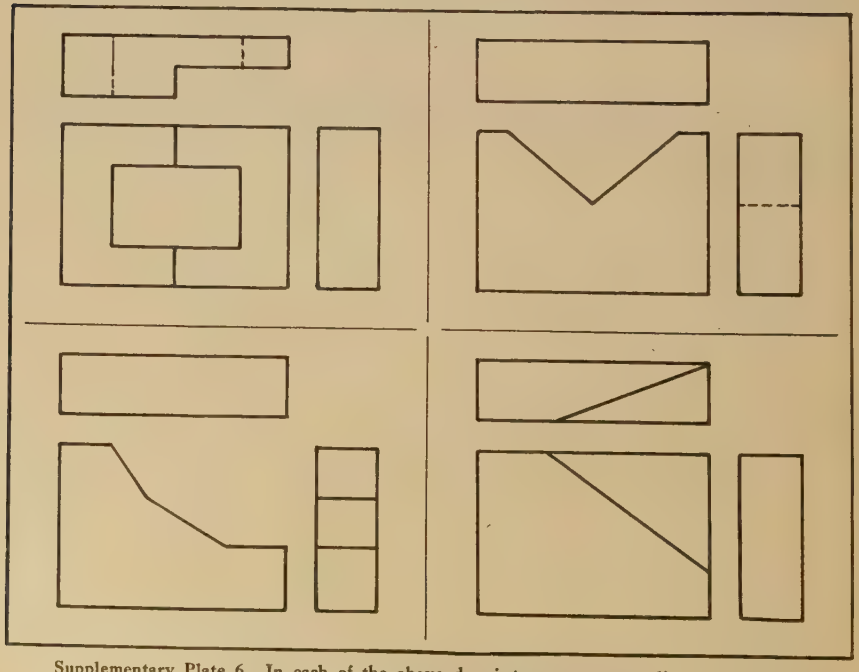


Plate 6A



Supplementary Plate 6. In each of the above drawings, one or more lines are missing. Make free-hand sketches supplying them

Lesson 7

I. *Purpose*

1. To learn something about curves and curved surfaces.
2. To make a drawing of an object having curved surfaces.

II. *General Information: Curves*

Most objects which draftsmen have occasion to draw have some curved surfaces. The most simple of these is the circle which is drawn with a compass.

Curved surfaces are used for a variety of reasons. Outside corners are rounded to make an object easier to handle, less likely to chip off at the sharp edges, and more pleasing to look at. Inside corners are rounded to prevent cracking, and to make the part easier to clean. Curves sometimes are stronger than straight lines. The arch of a bridge is an example of this. As a general rule, curves are more pleasing to the eye than straight lines. However, of all the kinds of curves, the circle is the least pleasing from this standpoint.

Other frequently used curves are the ellipse, the parabola, the hyperbola, the involute, the cycloid, and many others.

All of these are derived from higher mathematics and are mentioned here merely to acquaint the student with them.

Space does not permit us to describe the many interesting uses of these curves. As an example, however, the gears in an automobile have teeth, the surfaces of which are shaped like a portion of the involute. The headlight reflectors in the same car are parabolic in shape, which causes all the light rays reflected from them to be parallel.

Where mathematical accuracy is not necessary, curves other than the circle are usually laid out free-hand. When these are to be inked or care-

Fig. 14b. Note the pleasing use of curves in this concrete bridge. (Courtesy Portland Cement Assn., Chicago, Ill.)

fully penciled, a "French curve," like the one shown in Figure 7, is fitted to the line and used as a guide.

III. *The Problem*

To copy the drawing assigned, paying particular attention to the representation of the curved surfaces in all the views. (Plates 7C, B, and A, and T1 and 2.)

IV. *Suggestions for Procedure*

1. In the case of the Ring (Plate 7C), locate and draw the center lines first.
2. In Plates 7B or A, lay out the views as in preceding lessons, locate the centers, and draw the arcs.
3. Note that the limits of a cylindrical surface are straight lines in the other views.
4. In Plates 7B and 7A, the most important problem is to locate the points of tangency accurately. This should be done by drawing light construction lines through the points. These lines are to be erased from the finished drawings.

Questions

1. How many points of tangency are there in Plate 7B? In Plate 7A?
2. In the top view in Plate 7A, why are there four vertical lines?

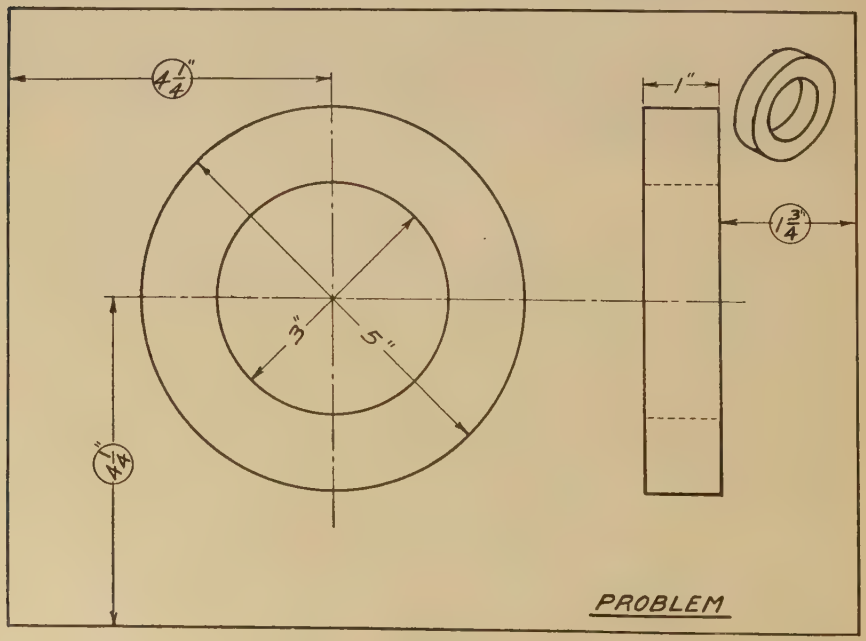


Plate 7C

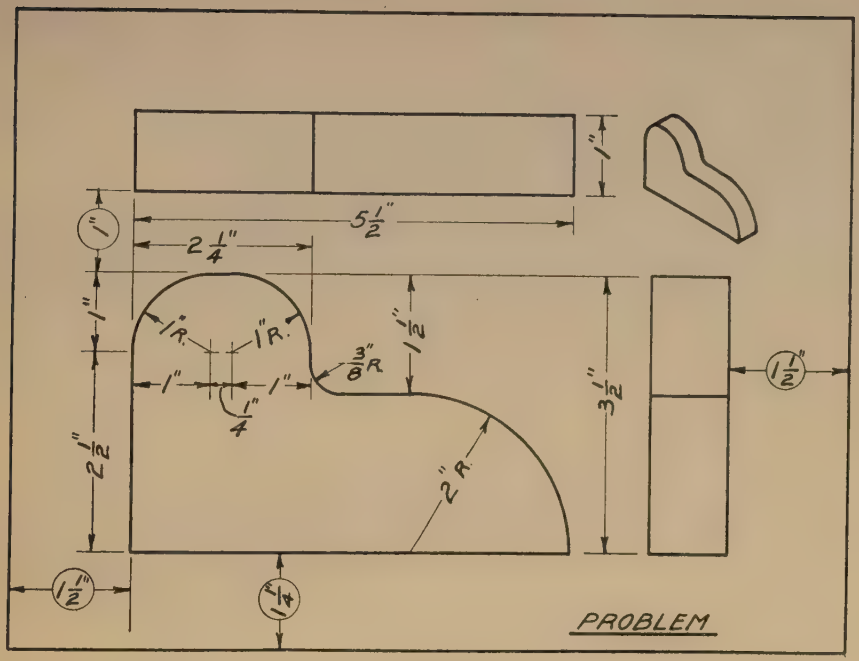


Plate 7B

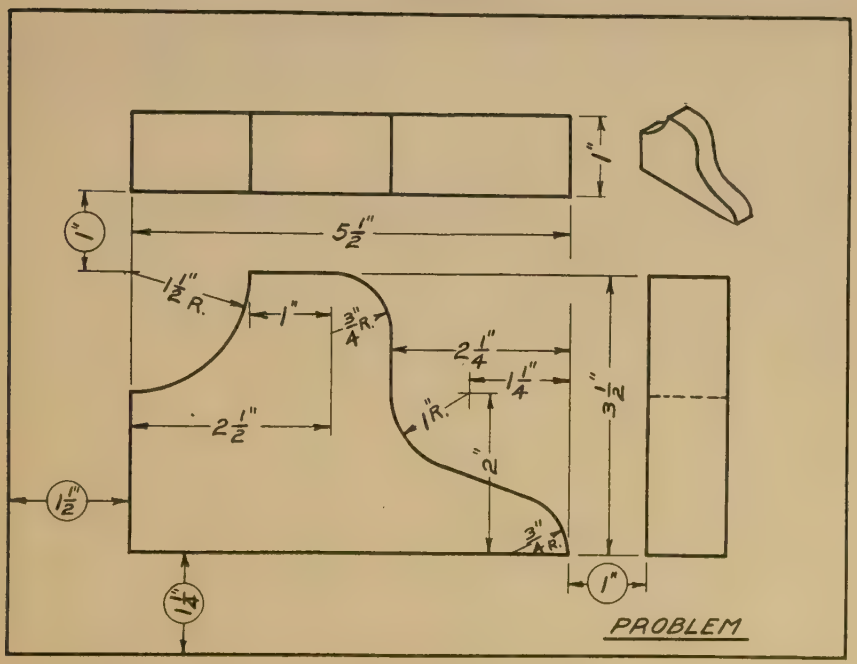


Plate 7A

Suggestive Test 1

Directions: Fill in the blanks with words which will make the statements correct.

1. About ———— times as much work can be done per man at the present time than at the time of Columbus.
2. Mechanical drawing is often said to be the ———— of industry.
3. A man whose business it is to make drawings is called a ————.
4. Mechanical drawing is becoming ———— and ———— important in industry.
5. Drawing boards are made of ———— ————.
6. The two parts of a T square are ———— and ————.
7. The head of the T square should be held against the ———— edge of the board.
8. The two triangles used by draftsmen are———— and ————.
9. A ———— pencil should be used for darkening lines on a drawing.
10. Vertical lines should be drawn from ———— to ————.
11. The height of the side view is the same as the height of the ——— ———— view.
12. Make three free-hand views of two of the pictorial sketches in Plates T1 and T2.

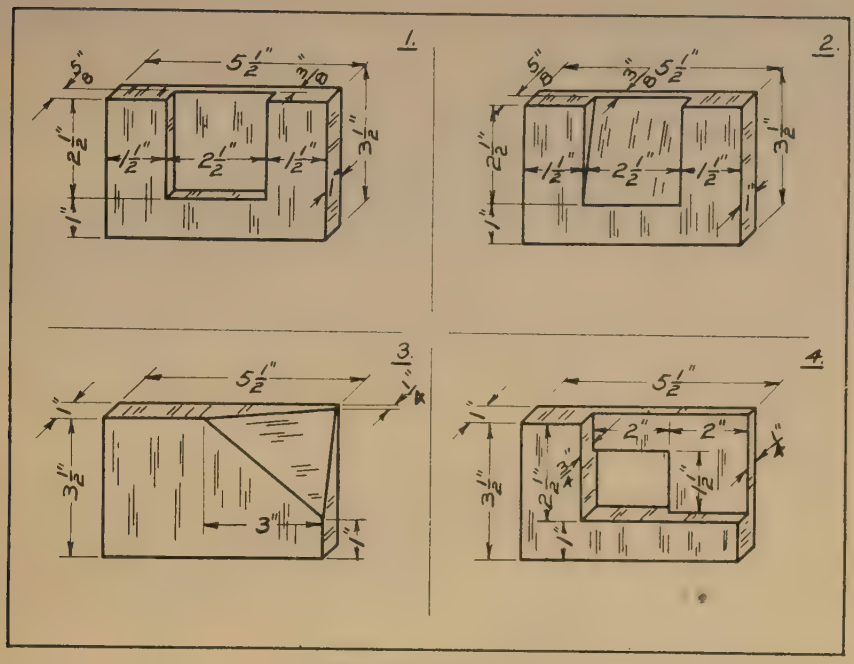


Plate T1. Test problems

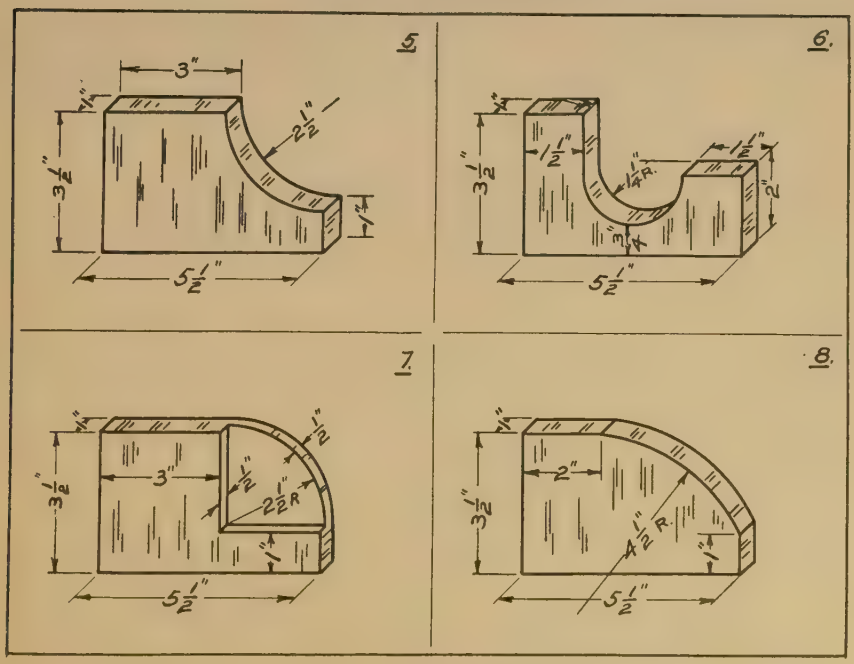


Plate T2. Test problems

PICTORIAL MECHANICAL DRAWING

Lesson 8

I. *Purpose*

1. To learn something of the principles of perspective drawing.
2. To gain some experience in making a simple perspective drawing as an aid in later free-hand sketches.

II. *General Information: General Principles of Perspective Drawing*

Everyone is familiar with common photographs and drawings which represent solid objects on flat surfaces. Such pictures and drawings show objects as they actually appear to the eye. Drawings which are made to give this effect are known as perspective drawings. Although the technical draftsman does not make extensive use of this type of drawing, it is desirable that he be acquainted with its principles and be able to make simple free-hand sketches of this kind. Such drawings are easily interpreted by anyone.

Perspective drawings may be made free-hand in the form of sketches, or with the use of instruments in the form of mechanical perspective drawings. It is not within the scope of this book, however, to go far into the details of mechanical perspective.

In order to make a drawing of an object so that it will produce the same effect on the eye of the observer as the object itself, we need first to recall how some common things appear. The example of the railroad track and telephone wires shows us that lines which extend away from the observer appear to converge, that is, draw closer together. All such lines which are at an angle with the observer converge until, if extended, they meet at a point on a level with the eye. Such a point is known as a "vanishing point." A drawing may have one or more vanishing points. Each set of parallel lines which lie at an angle with the observer has a vanishing point.

A drawing with one vanishing point is said to be drawn in parallel perspective. (See Plate 8C.) One with two vanishing points is drawn in angular perspective. (See Plates 8B and 8A.)

A horizontal line passing through the vanishing point or points is called the "horizon line."

Vertical edges or surfaces are represented by vertical lines on a perspective drawing.

If the distance from the observer, the size, shape, and position of an object are known, it is possible to make a mechanical perspective drawing which is accurate in every detail. Such drawings are somewhat difficult to make and consume much time.

One can develop considerable skill in making such sketches free-hand, if he will keep in mind the general principles discussed in the preceding paragraphs, and attempt at all times to make his drawing appear as much like the objects represented as possible.

Sources for further study:

Sturtevant: *Mechanical Pictorial Drawing*, pp. 93–128.

III. *The Problem*

To copy a simple perspective drawing. (Plates 8C, B, and A.)

IV. *Suggestions for Procedure*

1. Assume the position of the vanishing points at convenient places on the paper. (If you wish to locate these accurately, refer to the foregoing reference.)
2. In the parallel perspective (Plate 8C), note that the front view is a true view.
3. It is not necessary to use accurate dimensions in this drawing, but approximately the proportions shown should be used.
4. The angles of the lower edges of the object in Plates 8B and A were chosen for convenience. Other angles may be used.

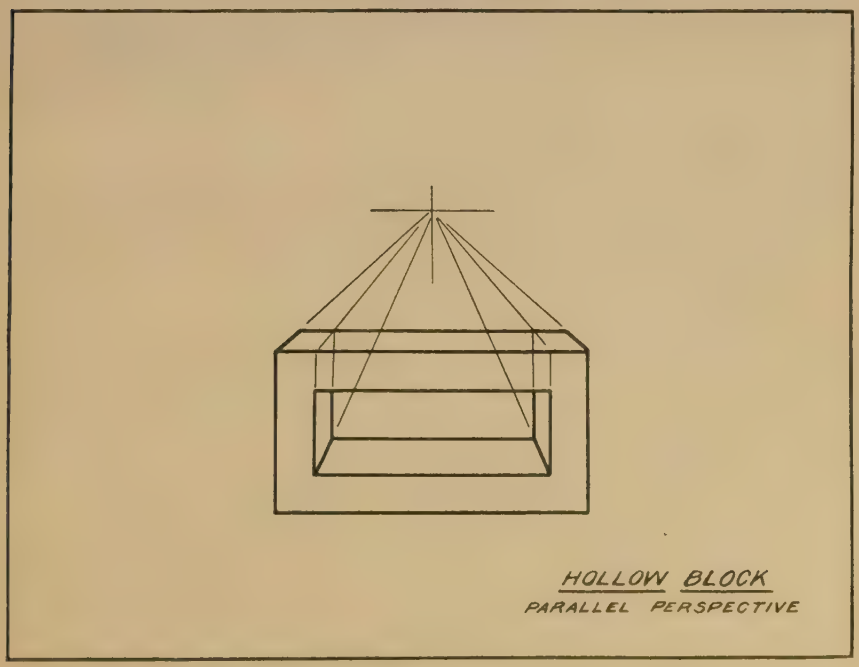


Plate 8C

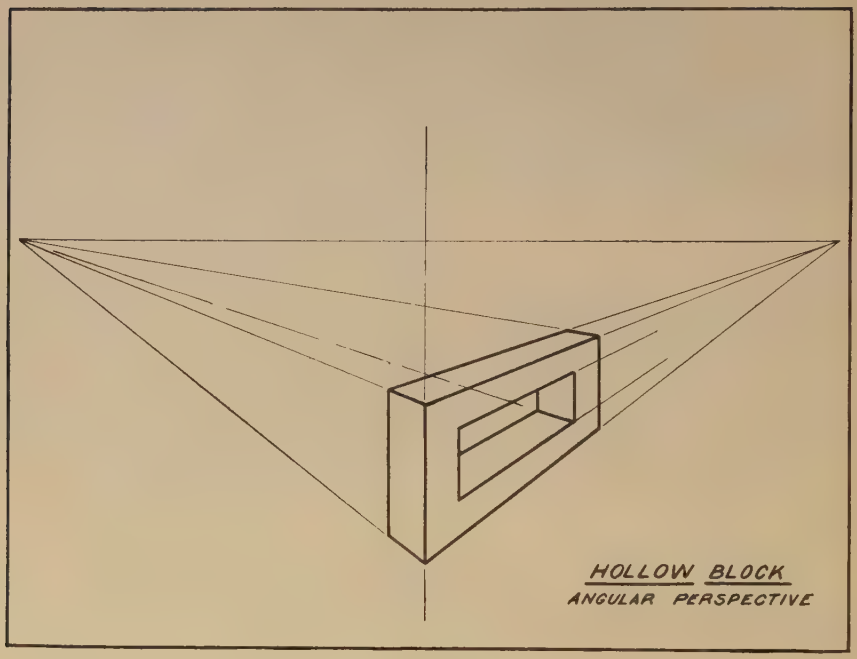


Plate 8B

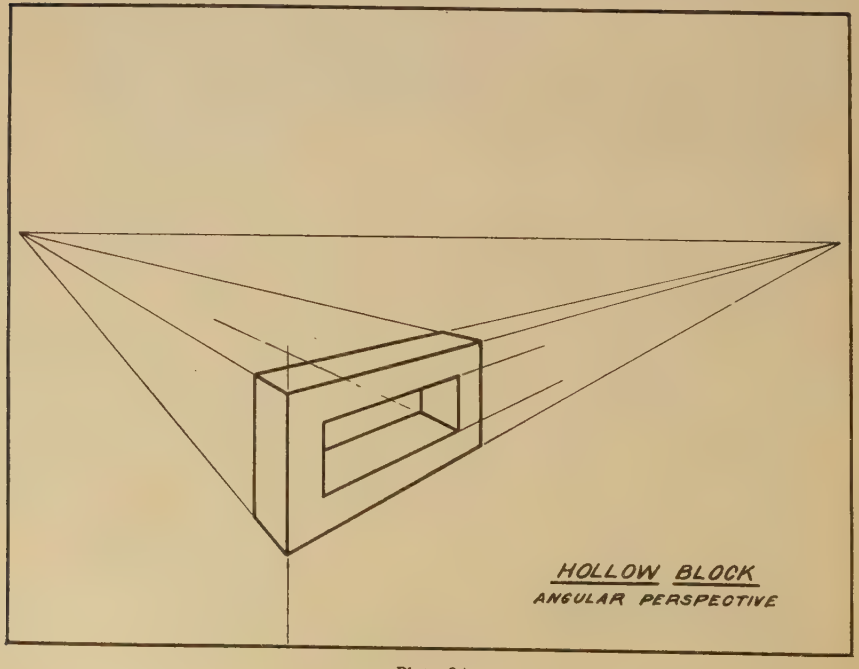


Plate 8A

Lesson 9

I. *Purpose*

1. To learn the fundamentals and uses of cabinet drawing.
2. To make a simple cabinet drawing.

II. *General Information: Oblique and Cabinet Systems of Pictorial Drawing*

In the preceding lesson we learned the meaning of perspective drawings. We found these are somewhat difficult to draw accurately and quickly. Several systems of pictorial drawing which approximate the perspective, but are easy to draw either mechanically or free-hand, have been developed. These approximate perspectives are quickly and easily drawn, and show lines and angles in such a way, that one familiar with the method knows at once the true shape of the object represented.

The most simple of these systems is *oblique drawing*. Here one surface and all others parallel to it are drawn parallel to the observer, making what is known as true views. All lines at right angles to this view are drawn upward to the right or left at an angle of 45°. (Note: When all of an object is above the eye level, these lines are drawn downward.) All vertical and horizontal lines are drawn full length. Slant lines are located by first finding points on horizontal or vertical lines through which the slant lines pass. One of the advantages of this type of drawing is that objects containing circles usually are so drawn that the circles appear on the true view. Where circles appear on other than the front view, the isometric system usually is used. (See Lesson 10.)

The oblique system makes the drawing of an object appear too large at the farther side, and causes it to seem longer than it should. This is partially corrected in cabinet drawing in which the oblique (45°) lines are made exactly one-half length (one-third and two-thirds length also are used instead of one-half); that is, in a drawing of a 2″ cube, the horizontal and vertical lines would be 2″ in length, while the 45° lines would measure 1″.

Cabinet drawing is so called because cabinetmakers use it extensively.

Pictorial drawings of this kind are easy to make and are very useful in quick free-hand sketches of small objects.

Sources for further study:

Sturtevant: *Mechanical Pictorial Drawing*, pp. 7–35.

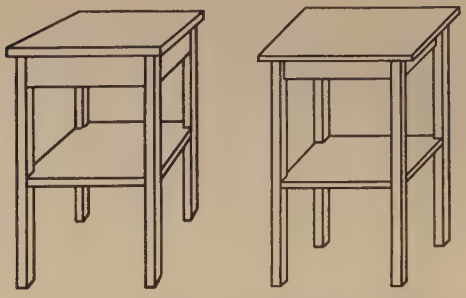


Fig. 15. These two drawings of the same table show the difference between a true perspective drawing and a cabinet drawing

III. *The Problem*

To copy one of the cabinet drawings in Plates 9C or 9B. In Plate 9A, the problem is to make a cabinet drawing from the orthographic drawing. Try to fix the system in mind.

IV. *Suggestions for Procedure*

1. Lay out the front view as if it were an orthographic drawing.
2. Draw the receding (slant) lines at an angle of 45°.
3. Make measurements on these lines equal to one half the true length of the distance represented.
4. Invisible lines are seldom drawn. (None are used in this lesson.)

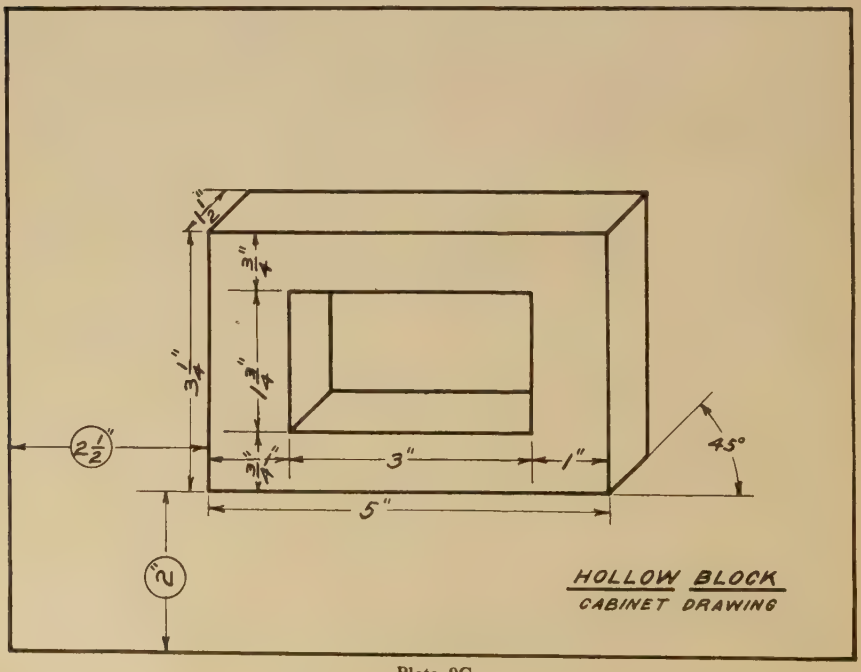


Plate 9C

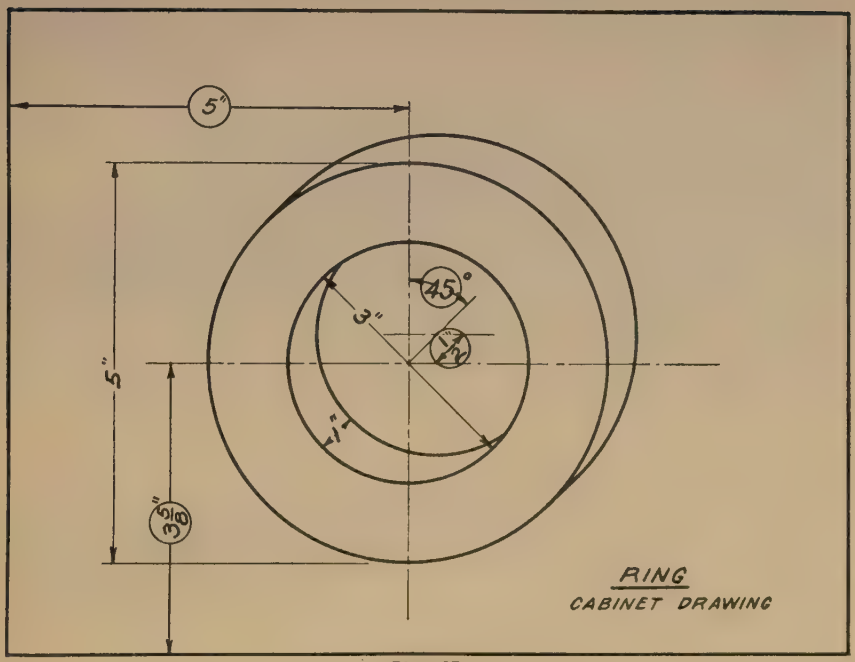


Plate 9B

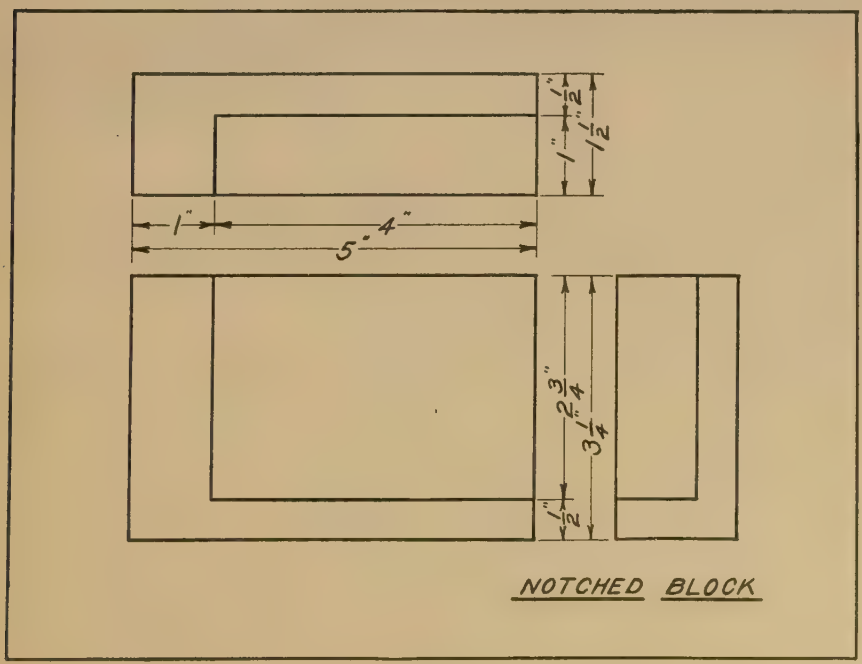


Plate 9A

Lesson 10

I. *Purpose*

1. To learn the fundamentals of isometric drawing.
2. To gain experience with its use.

II. *General Information: The Isometric System of Pictorial Drawing*

Isometric drawing is another system of approximate perspective. Like cabinet drawings, isometric drawings can be made free-hand or mechanically. They also show some distortion of shape, and appear larger than the object represented. However, they resemble a true perspective more than those made by any other approximate method. While in cabinet drawing it is difficult to draw circles except on the front surface, in isometric drawing they may be easily drawn on any surface. (Fig. 16.) This type of drawing is much used in pictorial shop sketching. It is also used by magazine illustrators, fire-insurance companies, and others.

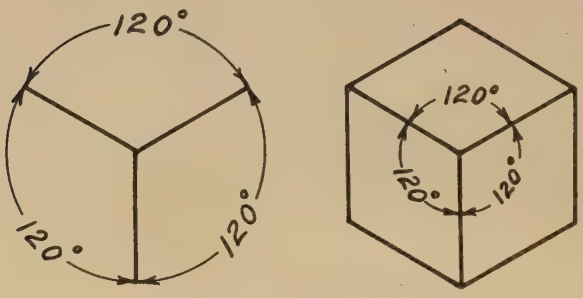


Fig. 16. Isometric axes

An object drawn in isometric is assumed to be placed with its corner toward the observer, and its horizontal edges sloping away at equal angles to right and left. It is from this characteristic that it gets its name, *iso-metric,* meaning *equal-measure.*

In making an isometric drawing, the following general rules should be observed. Upright edges are represented by vertical lines. Horizontal edges are shown by lines drawn at an angle of 30° with the horizontal. Lines representing horizontal and vertical edges are drawn full length. Straight lines, representing edges which are neither horizontal nor vertical, are known as nonisometric lines. These are drawn by first locating their ends on isometric lines.

Circles appear as ellipses drawn in isometric squares. (See Plate 10A.)

Sources for further study:

French: *Engineering Drawing,* pp. 106–116.

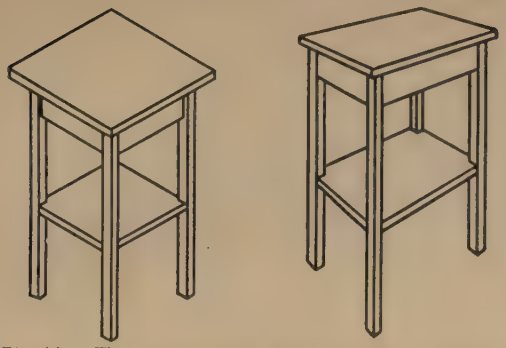


Fig. 16a. These two drawings show how a true perspective differs from an isometric drawing

III. *The Problem*

To copy the isometric drawing in Plates 10C or 10B. In Plate 10A, to make an isometric drawing from the drawing shown. Try to understand why and how each line is drawn.

IV. *Suggestions for Procedure*

1. Locate the point nearest you, as shown in the plates.
2. Draw the vertical and two 30° lines through this point.
3. Take measurements on these lines, and proceed as suggested by the drawings.
4. Study carefully the method for drawing isometric circles.

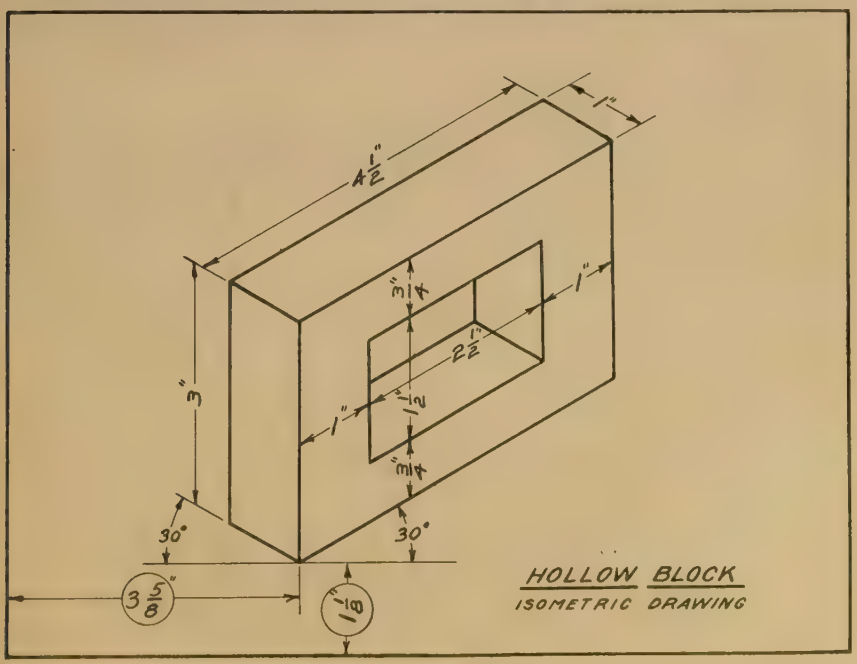


Plate 10C

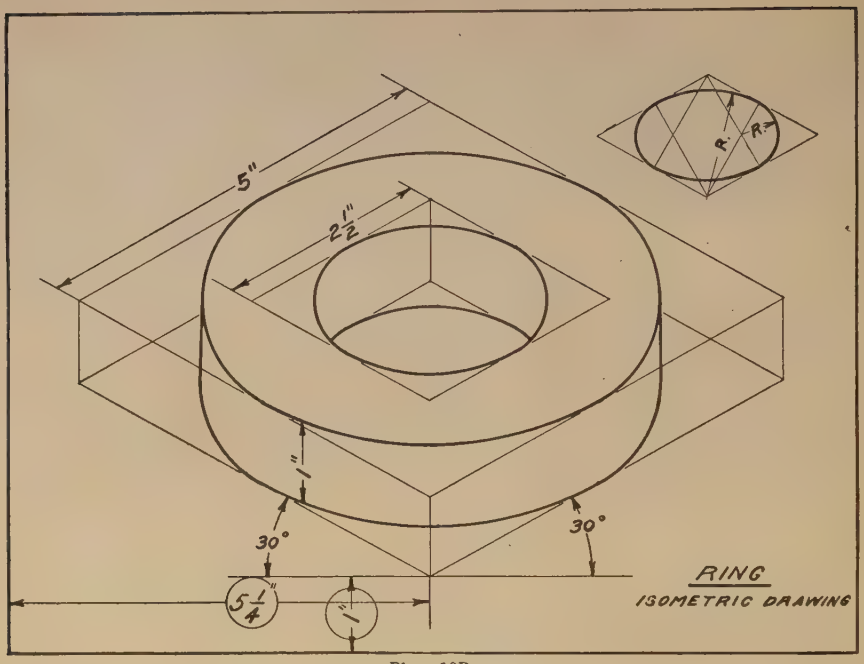


Plate 10B

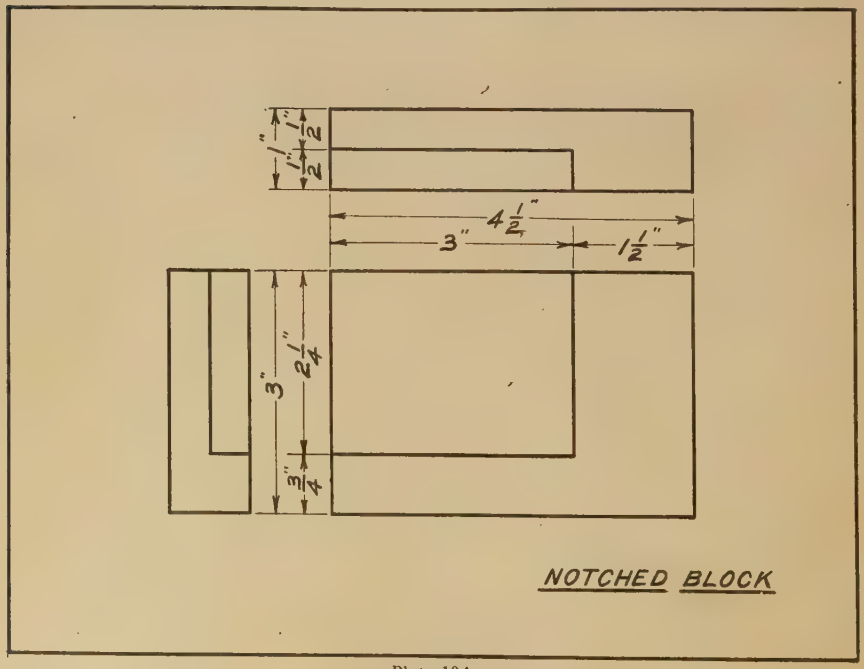


Plate 10A

LETTERING

Lesson 11

I. *Purpose*

1. To learn something of the origin of the alphabet of letters and its uses in free-hand lettering.

2. To study the forms of the Gothic alphabet and the Arabic numerals, and to begin the practice of lettering as used by draftsmen.

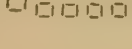
II. *General Information: The Draftsman's Need for Lettering*

Mechanical drawing has been referred to as the "graphic" language. Nevertheless, few drawings are complete and clear without the addition of a few printed words. These are in the form of titles, names of parts, dimensions, and notations. Free-hand printed letters are used for this purpose. A draftsman never writes longhand on a mechanical drawing, but rather prints each letter in a neat, uniform style. The one exception to this rule is the draftsman's signature or initials.

One who develops skill in such lettering will find it useful in many ways. Personal correspondence is often made more attractive by using free-hand lettering. It is also useful in making place cards, signs and posters, and labeling books. A good letterer derives constant satisfaction from its many uses.

Origin and Development of Letters. If asked to name the one invention which has been of most value to the human race, one could not do otherwise than mention *written language.* Without it, civilization could not go on, because there would be little exchange of ideas and no permanent records to pass on from generation to generation. The written languages of today were not invented in a single stroke, but grew up gradually over a period of several thousand years. They had their beginnings in picture writing, such as that used by the ancient Egyptians. The written language of the American Indians never progressed beyond this stage.

These pictures gradually changed to signs, and the signs to letters representing vocal sounds. For example, it is probably true that our capital A was originally a rough picture of a bull's head . This later became the sign . Its original meaning became lost, but the sign was still used and written , and later as at present.

It is thought that our numerals were originally straight marks arranged for convenient counting as follows,  , which developed into 1 2 3 4 5 6 7 8 9 0 .

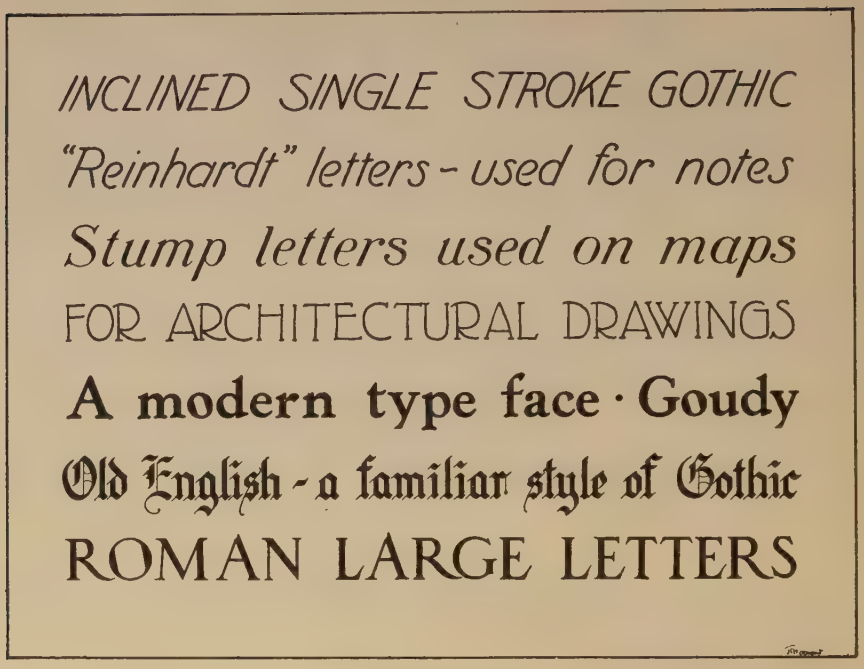

INCLINED SINGLE STROKE GOTHIC
"Reinhardt" letters - used for notes
Stump letters used on maps
FOR ARCHITECTURAL DRAWINGS
A modern type face · Goudy
Old English - a familiar style of Gothic
ROMAN LARGE LETTERS

Plate 11–1

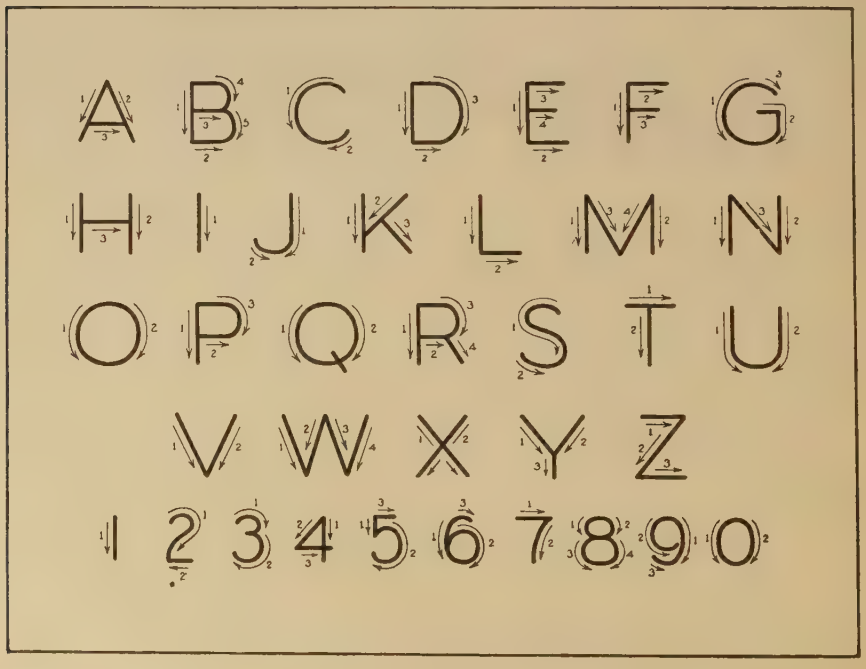


Plate 11–2

The complete story of the growth of the letter forms of our alphabet would occupy many thick volumes. For our purpose, it is enough to say that our letters are the result of a long evolution extending from the Egyptian, through the Phoenician, Greek, and Roman periods. We still use the letters of the Roman alphabet (capital letters only) as they were left for us in the stone inscriptions of two thousand years ago. Only the letters J, U, W, Y, and Z have been added since. The lower-case letters were first invented in the reign of Charlemagne, and are sometimes called the Carolinian letters.

The numerals of the Romans were combinations of letters and, being awkward for most uses, have been displaced by the Arabic numerals.

Variations of the Roman and Carolinian Letters. There are many modern variations of the Roman and Carolinian letters. The examples in Plates 11–1 and 11–2 will give the reader an idea of some of the more common of these which are of interest to the mechanical draftsman.

An examination of any popular magazine will reveal dozens of other styles of letters, each having an appropriate use in printing, but of no practical value in mechanical drawing.

References:

Taylor: *The Alphabet, Its Origin and Development.*

French and Meiklejohn: *Essentials of Lettering.*

Suggestions on Lettering. The ability to letter rapidly and well is important to the draftsman. The appearance of a drawing may be easily ruined by poor lettering. Poor lettering also may result in costly errors in the shop, because of illegible notes or dimensions.

As indicated in the preceding paragraphs, there are many variations of the alphabet. In this course, however, we will confine ourselves to the inclined single-stroke Gothic capitals. These letters are used because they are very legible and are quickly and easily made. In actual practice, architects, topographical draftsmen, and machine draftsmen, use special styles of lettering.

In pencil lettering, a 2H or H pencil should be used. A harder pencil follows the grain of the paper, and a softer one makes a blurred line. For ink lettering, Leonardt's ball-point pen No. 506 F or 516 F or the equivalent should be used for letters up to ¼" high. For larger letters use a speedball or Payzant type of pen of suitable size.

Very large letters are made with a show-card brush.

Fig. 17. Lettering pens

The stroke in free-hand lettering is a finger movement, not an arm movement as in handwriting. The order and direction of these strokes are important. They are shown in Plate 11-2, and should be carefully followed.

Proficiency in the making of the letters requires careful study of form, slant, alignment, and spacing, as well as faithful and intelligent practice. The letter forms may be observed from studying a sample alphabet. One should not assume that he already knows these forms, but should study each letter carefully. A common error in form is to make such letters as B, E, K, S, X, Z, and the figures 3 and 8 to appear top-heavy. The lower part of the character should be slightly larger than the top. Guide lines always should be used to insure uniform sizes and straight lines. Inclined letters should slant 60° to 70°, the best slant being 67½°. A triangle, similar to the drawing triangles, with a base of 2″ and an altitude of 5″ gives an angle of about 68°. The slant of a letter is the slope of a line passing through its center, as or .

Spacing is all-important in good lettering. It is difficult to give definite rules for spacing. In general, it is true that a space from one to two times the height of the letters should be left between the words. The space between letters within words should be about one sixth of the width of the capital M of the style being used. There are a number of exceptions to these rules, however, due to the irregular shape of the letters. For example, LT and FA should be spaced closer than HL and MI in order to give the same appearance. In spacing, then, one should attempt so to space the letters and words that they *appear* to be uniform distances apart. Avoid crowding.

References:

Miller: *Mechanical Drafting,* Chap. I.
French: *Engineering Drawing,* Chap. IV.

III. *The Problem*

To prepare a reference plate of single-stroke Gothic letters, paying particular attention to the form and proportions of each letter and the direction and order of strokes.

IV. *Suggestions for Procedure*

1. Copy the letters shown in Plate 11–2.
2. Lay out the spacing as indicated by the dimensions. Do not copy the dimensions.
3. Use a 2H drawing pencil.
4. Observe the direction and order of strokes as shown by the numbers and arrows in your plate.

//////////////// //////////////// ≡≡≡≡≡≡≡≡ ≡≡≡≡≡≡≡≡	ILTHEF ILTHEF ILTHEF ILTHEF HILT ILL THIEF LITTLE LEFT IF	//////////////// //////////////// \\\\\\\\\\\\\\\\ \\\\\\\\\\\\\\\\
V W A M N Y X Z K V W A M N Y X Z K VIEW WALK AN LEAVE KITE ALL	(((((((((((((((((((((((((((((( ))))))))))))))))))))))))))))))))	O C G Q U J D O C O C G Q U J D G Q O C G Q U J D U J O C G Q U J D D O
P R B S P R B S P R B S P R B S P R B S P R B S P R B S P R B S	SPRING SPUR RASP BUT UP BRONZE SPAR PRESS RUSH	A B C D E F G H I J K L M N O P Q R S T U V W X Y Z A B C D E F G H I J K L M N O P Q R S
NAME JOHN DOE WILLIAM RICE JOE GREEN	THE QUICK RED FOX JUMPS OVER THE LAZY BROWN DOG	1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 DATE 4-6-29 6-2-30 7-3-28

Plate 11–3

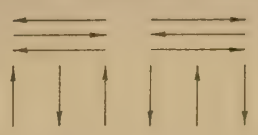
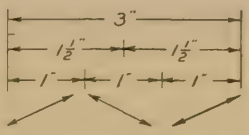
$1\frac{1}{4}$" $2\frac{1}{2}$" $3\frac{1}{4}$" $4\frac{1}{4}$" $\frac{1}{4}$" $1\frac{1}{2}$" $2\frac{3}{8}$" 6'-$6\frac{1}{2}$" $4\frac{1}{2}$" $1\frac{1}{4}$"X$2\frac{1}{2}$" PINE $\frac{1}{8}$" $\frac{3}{16}$"		
LINK LEVER CRANK GEAR ROD BEARING SHAFT KEY	TURN GRIND FILE REAM BORE DRILL COUNTERSINK	CAST IRON BRASS STEEL WROUGHT IRON LEAD TIN ZINC
STUDY THE FORM OF THE LETTER AND LEARN THE ORDER OF STROKES	ANYONE CAN LEARN TO LETTER WELL IF HE WILL PRACTICE	AN OTHERWISE GOOD DRAWING MAY BE RUINED BY POOR LETTERS
WORK SLOW WHEN YOU MUST WORK FAST WHEN YOU CAN	$\frac{3}{8}$"X2" STEEL CUT STOCK 12" 1" ROUND ROD 1" ROD 1" RIVET	LEGIBILITY AND SPEED ARE REQUIRED OF THE DRAFTSMAN

Plate 11–4

FREE-HAND SKETCHING

Lesson 12

I. *Purpose*

1. To become acquainted with the materials and methods used in making free-hand sketches.
2. To develop some skill in free-hand, pencil sketching.

II. *General Information: Uses, Materials, and Methods of Free-Hand Technical Sketching*

Finished mechanical drawings are made with the aid of special drawing instruments. However, all technical draftsmen find frequent use for free-hand sketching in which the general principles are the same as in mechanical drafting. Free-hand drawings have certain advantages. They are quicker and cheaper to make and in many cases more convenient. A large proportion of finished mechanical drawings are preceded by free-hand sketches.

Free-hand sketching has the following five general uses to the technical man:

1. It serves as an aid in working out mechanical designs.
2. It is frequently the preliminary step in laying out a mechanical drawing on the sheet.
3. It is used by the designer in transmitting his ideas to junior draftsmen who make the finished drawings.
4. It is used by the draftsman as a means of recording mechanical ideas obtained outside the drafting room, that are later to be used in finished drawings.
5. It serves as an aid in conveying mechanical information to others, as from foreman to workman, salesman to buyer, or teacher to pupil.

Skill in free-hand sketching is desirable for everyone, and a necessity for those engaged in industrial or mechanical work. Anyone can acquire this skill if he will practice systematically and consistently. The beginner will be surprised at the proficiency he can acquire after a few lessons.

The materials and items of equipment necessary for this work are few and inexpensive. They consist of paper, pencils, eraser, and rule.

The paper may be of a cheaper grade than that used for finished mechanical drawings. Any plain paper, which has a good writing surface

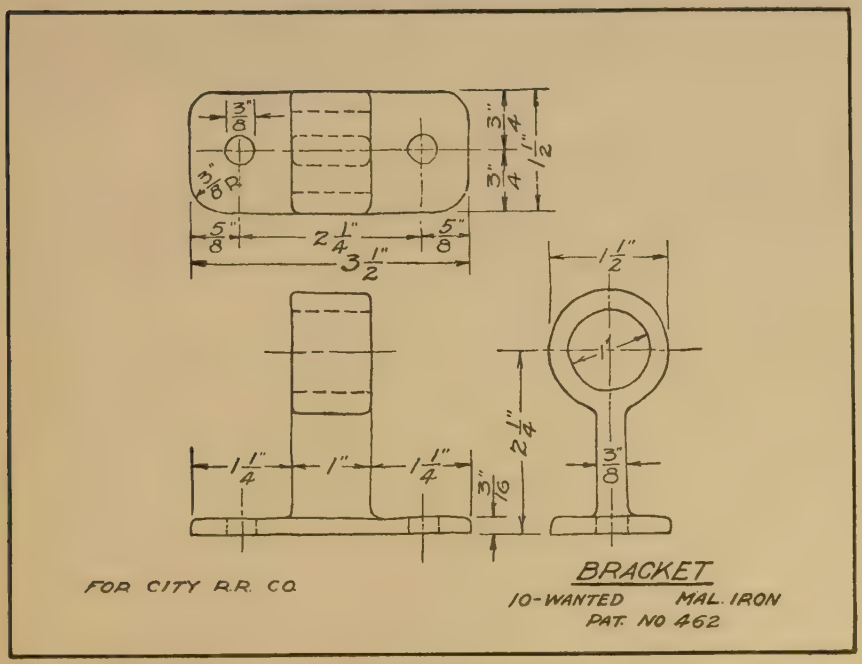
and is heavy enough to stand erasing, will serve the purpose. It may be used in pads or notebooks, or single sheets may be clipped or tacked to a drawing board. Cross-section paper ruled in ⅛″ or ¼″ squares also may be used. This is not recommended, however, except for beginners.

Pencils are made in several degrees of hardness. An H, F, or HB drawing pencil is suggested for this work. A common No. 1 lead pencil is also satisfactory for most papers.

A soft pencil eraser is a necessity, but should be used sparingly.

A rule is necessary for securing accurate measurements of the parts of the object sketched, if dimensions are to be placed in the drawing. However, in making the drawing, one should depend only on the eye for securing correct proportions.

Methods: Horizontal lines should be drawn from left to right with an arm movement. Vertical lines should be drawn downward. The pencil should be gripped about 1½″ to 2″ from the point, and held at an angle of about 45° with the surface of the paper and at right angles with the line. Tenseness of the muscles should be avoided. Circles may be drawn most satisfactorily by first drawing several radial lines and locating points equally distant from the center. (See Plates 12C, B, or A.)



Supplementary Plate 12

Sources for further study:

Zipprich: *Freehand Drafting,* Chap. I, par. iii.
French: *Engineering Drawing,* p. 250.

III. *The Problem*

To copy one of the accompanying plates. (Plates 12C, B, and A.) Pay special attention to the position of the hand and the method of holding the pencil.

IV. *Suggestions for Procedure*

1. Reproduce the lining problems shown in Plates 12C, B, or A.
2. Observe the suggestions under "Methods" in the General Information section of this lesson.
3. Long lines are made up of shorter strokes from ½″ to 1½″ in length.
4. Angles and distances are judged with the eye — not measured.

Note: Do careful work. A free-hand sketch should not be a rough, haphazard drawing. It requires the same careful attention to details as mechanical drawings.

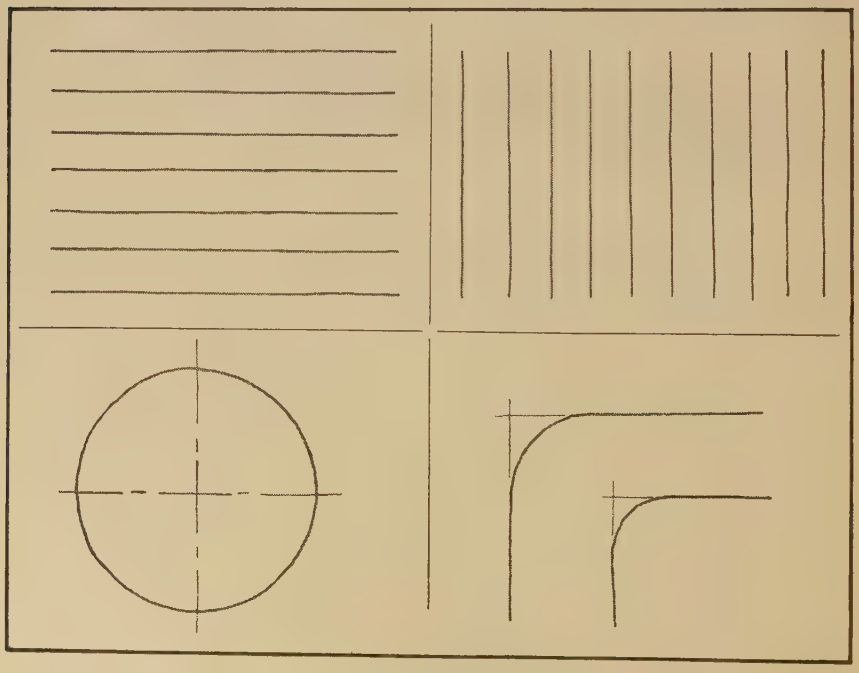


Plate 12C

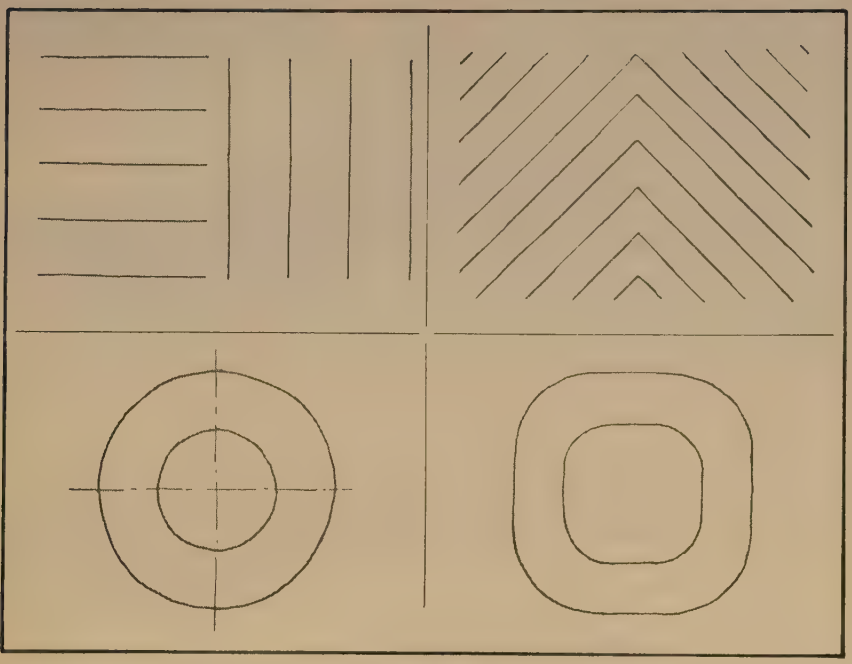


Plate 12B

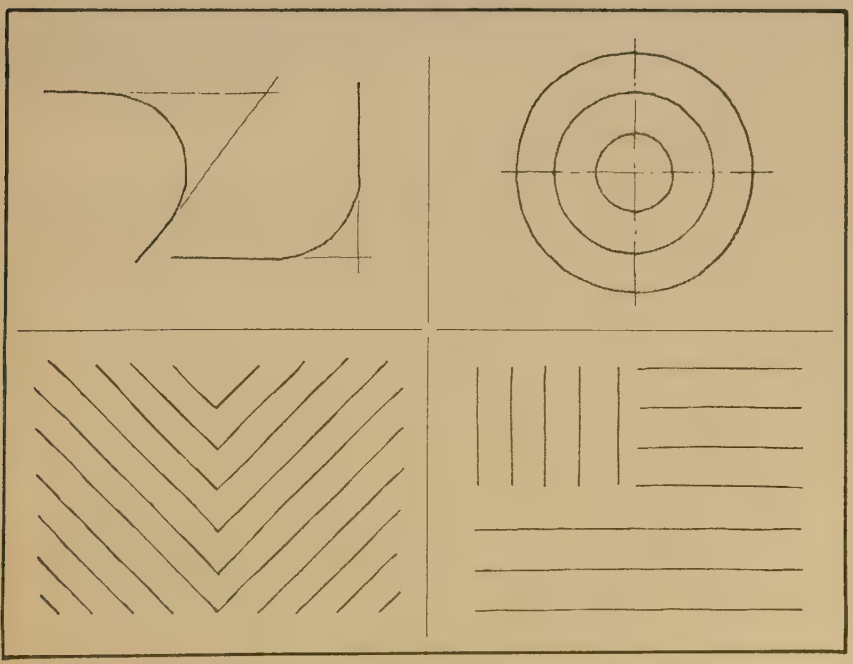


Plate 12A

MACHINE DRAWING

Lesson 13

I. *Purpose*

1. To learn something of the kind of work done by a machine draftsman.

2. To apply what has been learned about free-hand sketching and orthographic drawing to a simple machine drawing.

II. *General Information: The Work of the Machine Draftsman*

We are constantly being made aware of the multitude of machines and mechanical devices, ranging from locomotives, automobiles, and airplanes to washing machines, typewriters, and watches, which surround us in everyday life. All of these first originated in the minds of inventors or designers.

In order that these devices and machines may be manufactured, it is necessary that the designer transmit his ideas to workmen. This is done by means of the graphic language previously mentioned as orthographic drawing. Hence, every complete factory engaged in the making of mechanical things must have a drafting department where drawings are made which show the size, shape, and arrangement of the parts of the product manufactured in the factory shops.

The workmen engaged in making this type of drawings are known as machine draftsmen. The workmen in the shops must be able to read and understand these drawings. In addition to this ability, the machine draftsman must be able to use judgment in the selection and arrangement of views so that the drawings may be made rapidly and cheaply, and at the same time so clear that there can be no possibility of errors in the shops due to misunderstanding of the designer's meaning. Skill and judgment in making drawings is, however, not sufficient in itself. The machine draftsman also must possess a wide knowledge of the strength, wearing qualities, hardness, costs, etc., of the materials used in the specialty which his company manufactures. He should be familiar enough with the tools, machines, and methods used in the shops to enable him to work out feasible and economical plans for manufacturing the things he draws. Frequently, slight changes in design result in great savings in the cost of manufacture.

One should not make the error of thinking that the major part of the machine draftsman's time is consumed in designing and drawing new

machines and devices. This is frequently an important part of his work, but he is more often employed in making slight changes and improvements in machines already existing. These changes are necessary because of changes in the uses of the product, changes in methods of manufacture, or changes in materials used.

Following are examples of the kinds of problems with which the machine designer must deal:

In February, 1919, it was decided to put a self-starter on the Model T Ford motor. The Ford engineers and draftsmen were required to change the design of the engine block to provide a place to put the starter.

A large manufacturer of farm machinery found that certain gears in the tractor they were making would strip when overloaded. The engineers and draftsmen were called upon to design and furnish drawings of suitable gears which would not strip.

A manufacturer of hairpins found that with the coming of bobbed hair a new type of pin was needed. He easily designed a suitable pin, but his draftsmen were called upon to do the more complex task of designing a new machine to make the new pins cheaply.

A maker of electric-power-generating machinery sold boilers, engines, pumps, generators, etc., to a school which wished to generate its own electric current. The draftsmen were asked to provide installation plans showing where and how the equipment was to be placed.

The drawings which you will be required to make or read in this chapter are very simple examples of the kinds of things a machine draftsman must be able to draw and about which he must have a great deal of information.

Sources for further study:

Visit the factory and drawing room of a machine-manufacturing plant.

Fig. 17a. Drafting room of a large corporation

III. *The Problem*

To make a complete three-view free-hand sketch of one of the machine parts shown in Plates 13C, B, and A.

IV. *Suggestions for Procedure*

1. Draw all lines free-hand. Do not use a straightedge or compass.
2. The student should depend on his judgment for dimensions and proportions. Do not measure with a scale.
3. Decide how the end view should appear before starting to draw.
4. Lay out the views with light lines first, and then darken them in. The procedure used in previous lessons should be used, except that lines are made free-hand.
5. Make the end view as a test of your understanding of the drawing.
6. If you have time, make a pictorial sketch, using cabinet drawing.

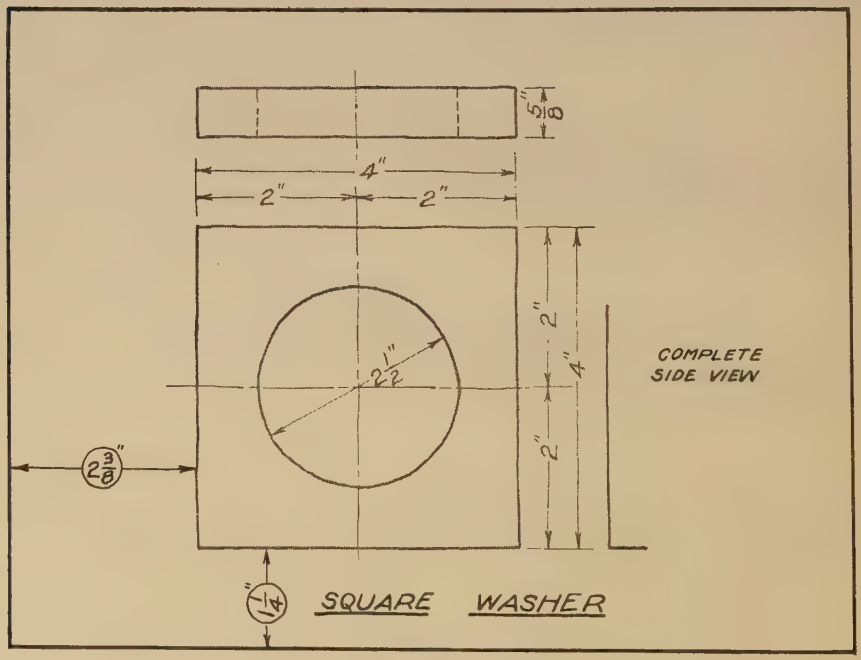


Plate 13C

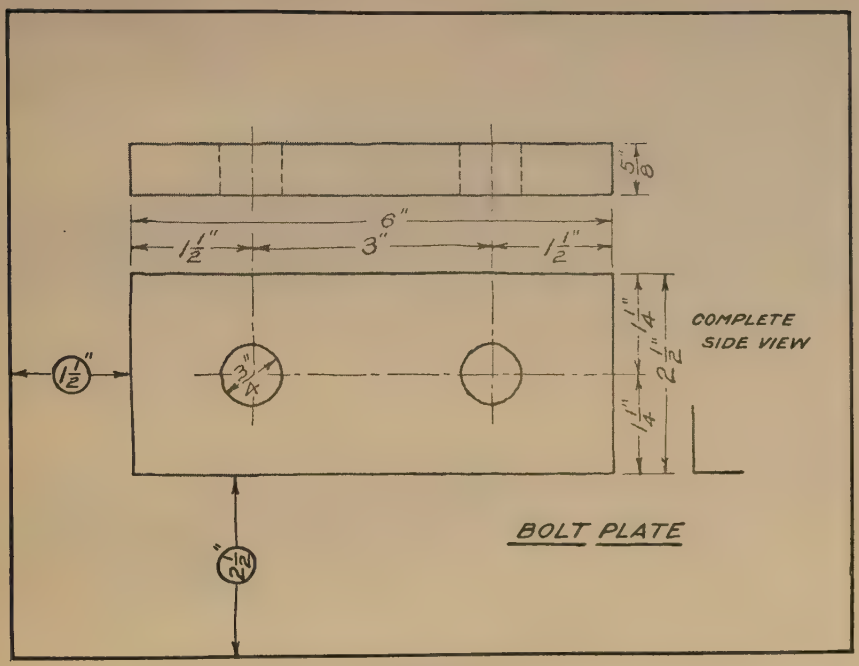


Plate 13B

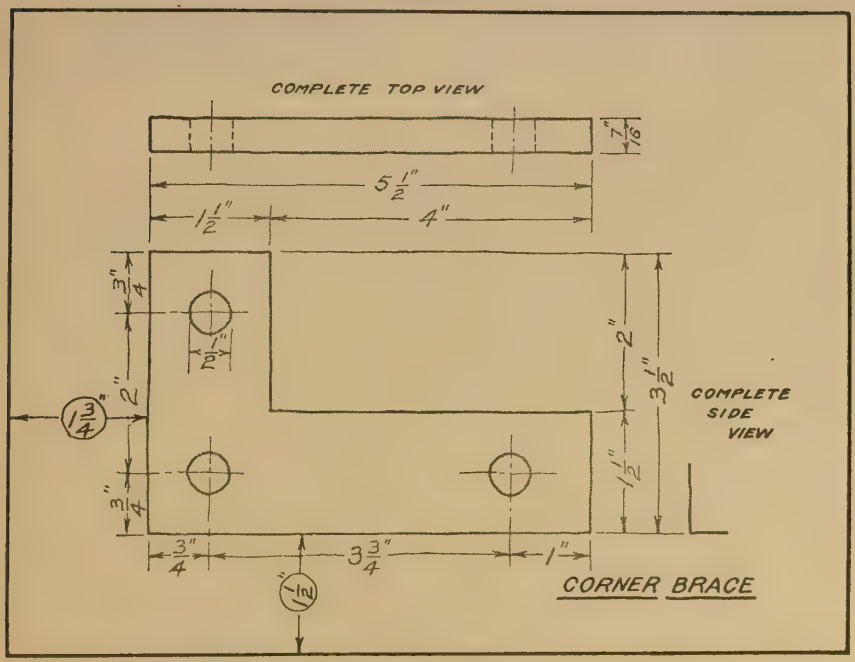


Plate 13A

Lesson 14

I. *Purpose*

1. To learn something about the division of work among employees in the typical drafting room.

2. To apply what you have learned about such things as circles, tangents, and center lines, to a problem in machine drawing.

Refer to Lessons 3 and 5.

II. *General Information: Specialized Workers in Machine Drafting Rooms*

It is possible for a boy with a high-school education, or less, to obtain a position in a drafting room and to advance to a fairly well-paid and responsible place, if he is willing to work on the job and to go to evening school or take correspondence courses. By all means, the best thing to do, if it can be arranged, is to go to a university and take an engineering course. However, if a boy is interested in this kind of work, he can succeed without the advanced education.

The first position offered the beginner is usually that of a combination office and blue-print boy. The work consists of running errands, filing blue prints and drawings, making blue prints, and making oneself generally useful. In the larger drafting room, a boy might do nothing but make blue prints. The making of blue prints is described in Lesson 24, and will not be discussed here.

If the boy shows an interest in his work, he will be advanced, after a time, to the position of tracer, and will be required to trace or copy the drawings of experienced draftsmen.

Accuracy and neatness in drawing lines and in lettering are essential in this work. This provides an unusual opportunity for the boy to learn how to draw, as he has a chance to study the drawings of experienced men.

The next step up will be from tracer to detailer. The detailer draws and dimensions the several parts of the machine which is sketched or hurriedly drawn by the designer. The time of the designer is too valuable to be used in figuring out and "drawing up" the simple parts. This task is left to the detailer.

The position above the detailer, is that of designer, who is usually a mechanical engineer. He works out the machine on paper, but seldom takes time to make accurate detailed drawings to scale. Often he works free-hand, and rapidly sketches the machines or tools to be made. These sketches are passed on to the detailer who works out the exact sizes, decides the material from which the part is to be made, and makes the

finished drawing. This is traced by the tracer, and a print is made by the blue-print boy.

The usual preparation for mechanical engineering is a four-year course in some good engineering college, but the boy who is unable to obtain a college education may secure a position in the drafting room and succeed as stated in the foregoing paragraphs.

A good head for mathematics, good eyesight, and a liking for solving mental problems are necessary to success. The ability to make neat lines and good letters may advance a boy to the position of tracer, but if one

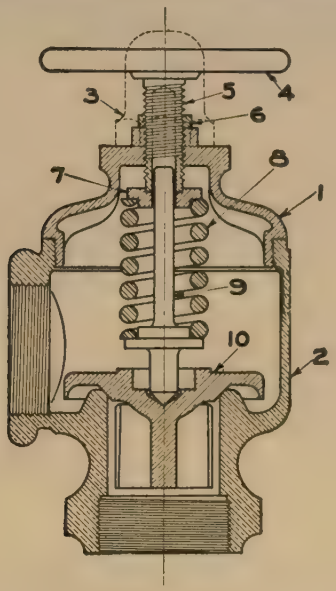


Fig. 17b. Water-relief valve. 1, valve bonnet; 2, valve body; 3, cap; 4, handwheel; 5, compression screw; 6, lock nut; 7, spring follower; 8, spring; 9, spindle; 10, valve proper. This illustrates an assembly drawing arranged for catalog use

expects to become a mechanical engineer, he must have more than average ability in mathematics. A boy who finds high-school mathematics difficult and distasteful should not enter this kind of work.

Working conditions in the drafting room are good. The drafting room is well lighted and the work is clean. The delight of constructive effort is not to be ignored.

To the man who enjoys seeing the results of his efforts put into practical use in the form of machines, buildings, and the like, there is no more satisfying work than that of the draftsman. Imagine, for example, the feeling of satisfaction that must have come to the men who helped design the motor which carried the first airplane across the Atlantic, or who prepared the plans for such a structure as Boulder Dam, the Washington Monument, or a great battleship. It is true that such technical

experts do not receive publicity equal to that given to soldiers, statesmen, and other public servants, but their contributions to the well-being of mankind are none the less important.

The objections to the drafting room as a place of employment are indoor work, lack of exercise, and rather low wages. These are offset by opportunity for advancement to the position of designer, engineer, or executive.

Sources for further study:

Gowin, Wheatly, and Brewer: *Occupations,* pp. 264–276.
Sackett: *The Engineer: His Work and His Education.*

III. *The Problem*

To copy and complete one of the drawings of cast-iron machine parts shown in Plates 14C, B, and A.

IV. *Suggestions for Procedure*

1. Locate and draw center lines.
2. Mark points of tangency before darkening lines.
3. Do not write in dimensions.

Note: The end view would not be necessary in these drawings, but is required here as a test.

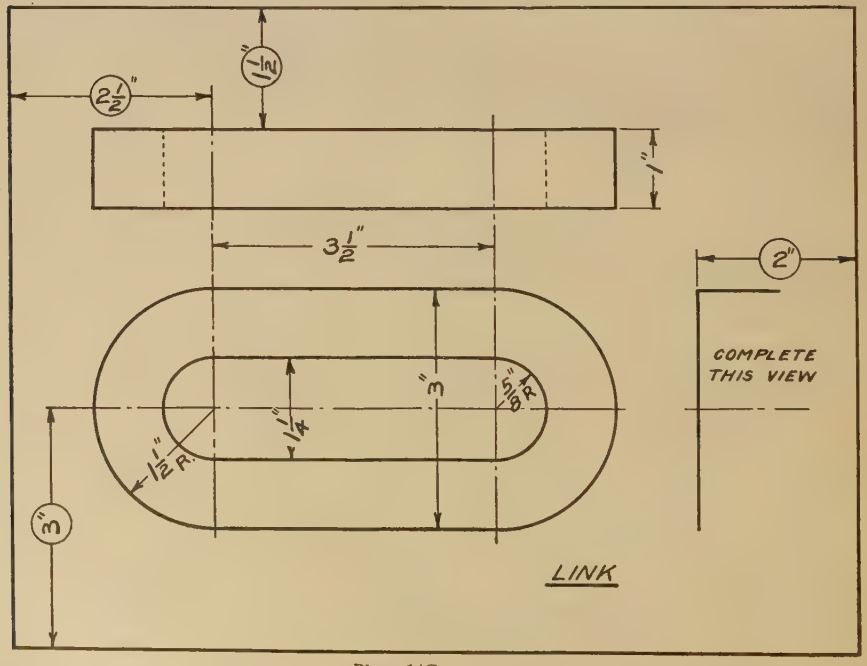


Plate 14C

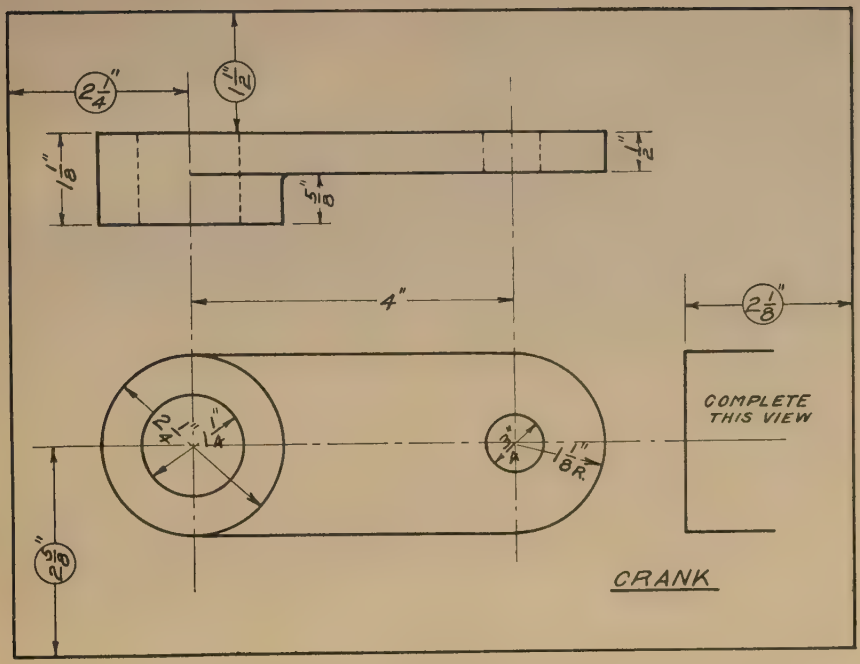


Plate 14B

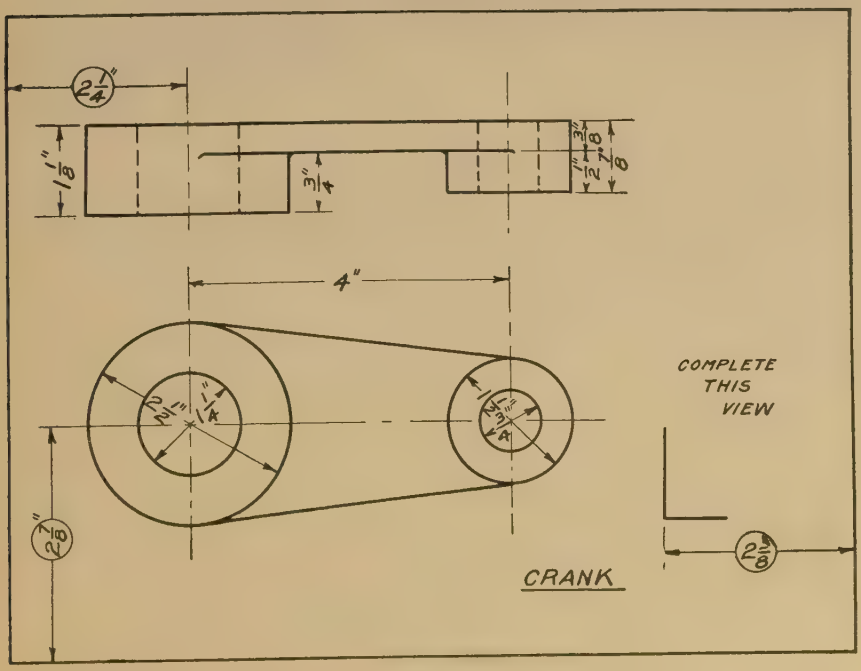


Plate 14A

Lesson 15

I. *Purpose*

1. To learn how castings of machine parts are made, and the meaning and uses of bearings and bushings.
2. To make drawings of the above parts, making use of "sections."

II. *General Information: How Castings Are Made*

A casting is a piece of metal formed into a special shape by pouring molten metal into a prepared mold. The cylinder block of a gasoline engine or the sections of a steam radiator are examples of the many things made in this way. Cast iron has the advantage of being very rigid and stiff. Its chief drawback is its brittleness. It breaks easily compared with wrought iron or steel.

When a cast-iron part, such as the shaft support shown in Plate 15C, is to be made, the following steps are necessary:

1. The making of a drawing which gives all the information about size, shape, and materials.
2. A "pattern," which is a duplicate of the object, made of wood or some other material easily worked, is made by a tradesman called a patternmaker.
3. The pattern is taken to the foundry where a *mold* is made by packing sand around it.
4. After removing the pattern, molten metal is poured into the mold.
5. The casting is removed from the sand and sent to the machine shop, where it is finished by chipping, filing, grinding, turning, polishing, etc.

Patterns often are made in several pieces so that they can be removed from the sand without breaking the mold. Such patterns are called "split patterns." A pattern is always made a little narrower at one side to make it easier to draw it from the sand. This is called the *draft* of the pattern. Large holes in a casting, as the inside of a steam radiator, are made by placing in the mold properly shaped *cores* of baked sand and molasses, reënforced with wire. After the casting has cooled, the core is broken up and the sand shaken out. Cast iron shrinks about $\frac{1}{8}''$ per foot in cooling; hence, the pattern is made enough larger to allow for this. A measuring rule, called a "shrinkage rule," is used by the patternmaker.

A knowledge of the patternmaker's work is valuable to the machine draftsman in the designing of castings so that they can be easily made.

Sources for further study:

Trade Foundations Based on Producing Industries. pp. 324–329.
Field trip to a foundry.

Arthur A. Strong

Bearings and Bushings. Power is transmitted from engines and motors by means of belts, pulleys, and gears mounted on shafts. The shafts are usually of steel. They are supported by bearings. The purpose of the bearing is to hold the shaft rigidly in place, and allow it to turn with as little friction as possible.

Boxes, brackets, and supports are other names for bearings which are of many types. Some are solid, and some are split or divided so that the upper part may be removed. Sometimes the shaft runs in the cast iron of the bearing, but where any great speed is required, the bearing is lined with a softer metal like babbitt or brass, so that the friction is less. Babbitt metal is made of 88.9 per cent tin, 7.4 per cent antimony, and 3.7 per cent copper.

Bearings must be lubricated and usually are made with an oil hole or oil cup or some similar device for this purpose. Oil prevents excessive wear and overheating through lessening friction.

The softer metal of the bearing is sometimes poured into the bearing in a molten condition, or the babbitt or brass bushing may be made separately and driven into the bearing.

One advantage of the bushing of soft metal is the lessened friction, and another is that bushings may be replaced at a low cost, thus making the bearing as good as new. It is also easier to replace a bearing than a shaft. The part of a shaft which revolves in the bearing is called a "journal."

Besides the plain bearing, there are ball bearings, roller bearings, and tapered roller bearings. These latter types are more expensive, but much better, as they reduce the wearing surface.

Sources for further study:

Kent: *Mechanical Engineer's Handbook.*

Sections. It is often difficult to show the interior of an object clearly when too many dotted lines occur in the drawing. To eliminate this difficulty, the draftsman often draws certain views of the object as if a portion of it were removed. A view made in this way is called a "sectional view." In such views dotted lines are frequently omitted.

In such a view, the interior of the object is represented with solid lines, and the portions which are assumed to have been cut through are shown by drawing fine diagonal lines, called "crosshatching," across them.

The cutting is only imaginary, and the sectioning of one view has no effect on the others. The cutting plane may be passed through the object at any point, but it is quite common to draw the object as though cut along the center line.

There are many uses and kinds of sections. Many of them are conventional; that is, they are not drawn exactly according to rule, but are changed to make the drawing clearer. Plate 17B illustrates this point. Where there is an odd number of spokes in a wheel, or teeth in a gear, or holes in a plate, the section is drawn as if the number were even. How would the section in Plate 17A look if it were a true sectional view?

Sources for further study:

French: *Engineering Drawing*, p. 85.

III. *The Problem*

Make a complete mechanical drawing of one of the objects represented in Plates 15C, B, or A. Observe carefully how the sectional views are made. In Plates 15C and B complete the views indicated.

IV. *Suggestions for Procedure*

1. Lay out the views as in previous drawings.
2. Practice drawing section lines on a piece of scrap paper before working on the drawing. They should be about one half the weight of the outlines, spaced about 1/16″ apart, and drawn at 45° from the lower left to the upper right.
3. Note the "draft" provided on the shaft coupling in Plate 15A.

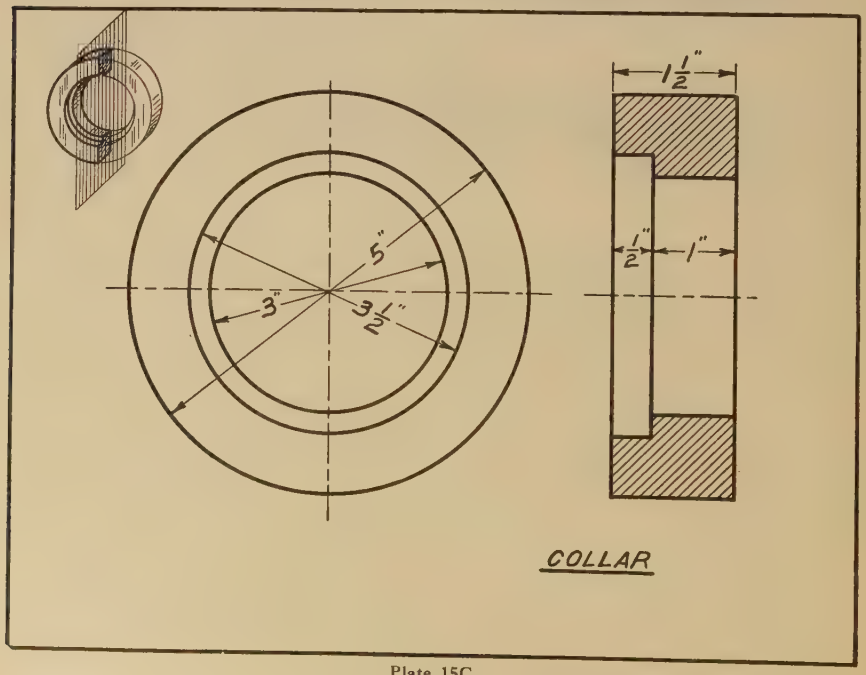


Plate 15C

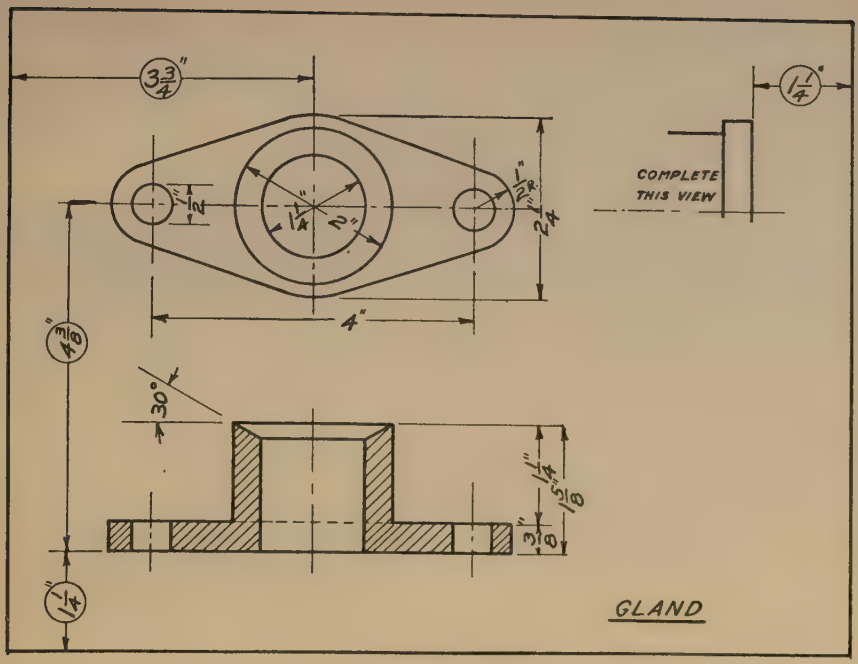


Plate 15B

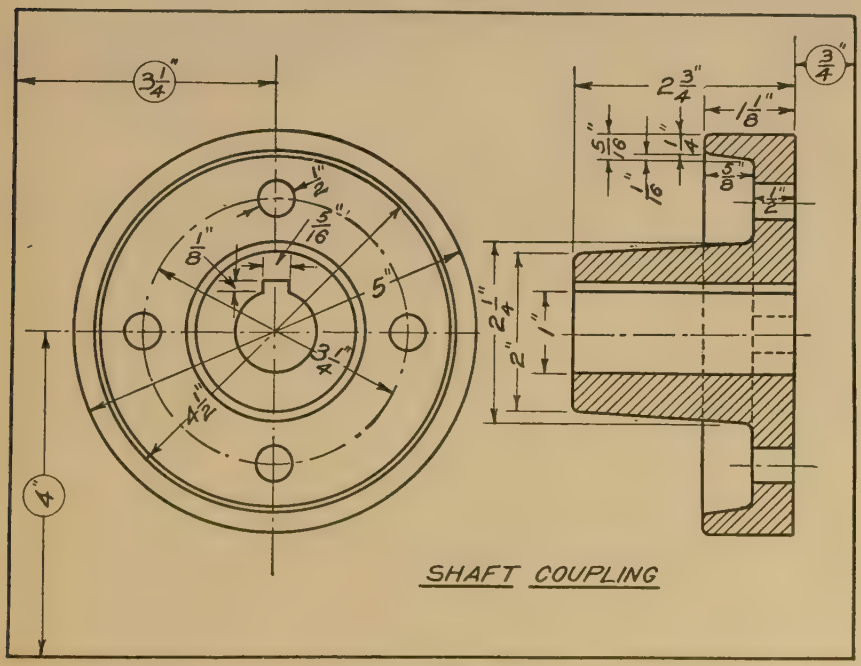


Plate 15A

Lesson 16

I. *Purpose*

1. To learn some of the rules and methods of dimensioning (size description).
2. To apply this knowledge in dimensioning several simple drawings.

II. *General Information: Dimensioning*

In the lessons up to this point, the student has been concerned only with shape description in drawing. The size of an object in all its details is given by means of figured dimensions lettered in the drawing. This part of drawing is often referred to as "size description."

Accurate size description is becoming more and more important in the machine-manufacturing industries of today. This change is due to the use of what is known as *quantity-production* methods. By this we mean that hundreds and often thousands of parts of machines are made from one drawing. Many different workmen work on one part, each one performing some small part of the work. Each man's work must be exactly right when he passes it on to the next man, and finally the completed part must fit some other part which the workmen on the first part do not even see. When all the parts are brought together, they must go together perfectly without additional grinding or fitting. This means that the draftsman must provide all dimensions for each part, and that each piece often must be accurate to within a few thousandths of an inch. Nothing can be left to the judgment of the workmen. One of the best-known examples of this is in the manufacturing of automobiles. Plate 16A shows how dimensions are placed in drawings in different situations.

There are several general rules for dimensioning a drawing. The experienced draftsman learns to use his judgment in the selection and placing of dimensions so as to make them as clear as possible.

Dimensions are usually placed outside of the drawing or between the views, so that the added dimension lines will not be confusing to the reader.

All dimensions should be placed in the drawing so that they may be read from either the bottom or the right side of the sheet.

Figures are placed at or near the middle of the dimension lines and at right angles to them.

Arrowheads are placed at the ends of the dimension lines to indicate exactly from which points the measurements read.

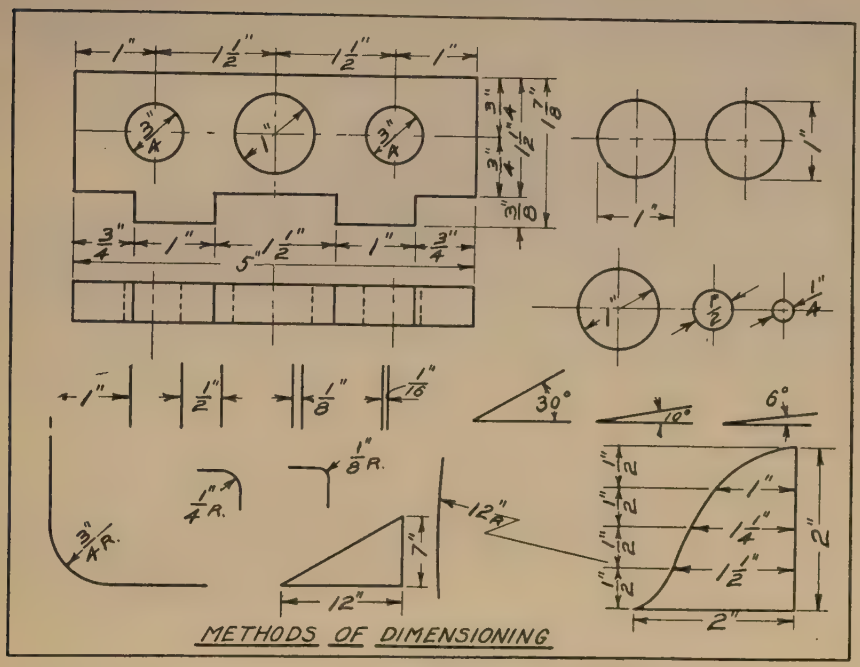


Plate 16A

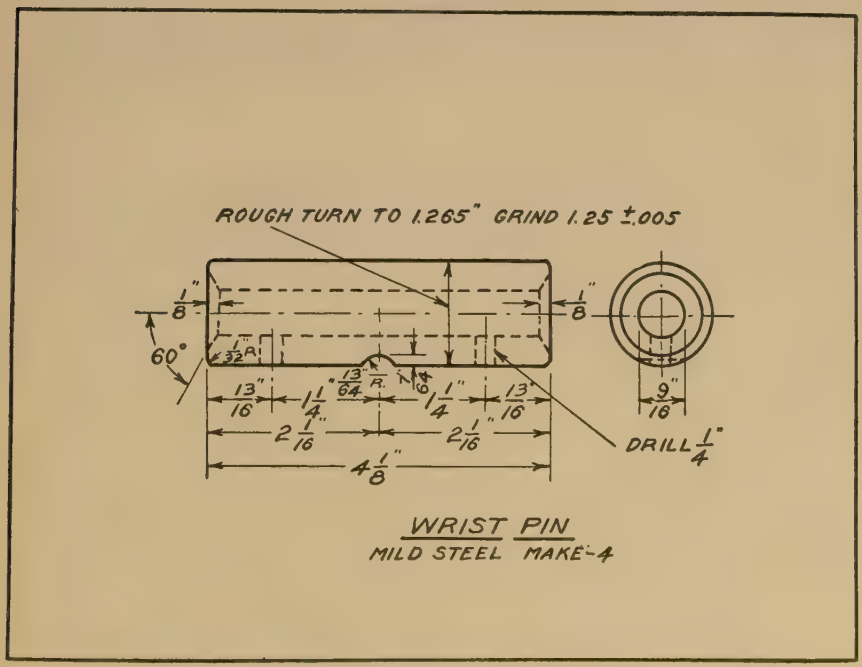


Plate 16B. Size description often is more difficult than shape description

Dimension lines are light enough to be easily distinguished from the lines of the drawing. They are usually not more than one half the weight of the outlines.

Dimensions should be given in such a way as to be most convenient to the workman. For example, in dimensioning round holes, the *diameter* is given if he will use a drill, and the *radius* is more convenient if he must lay out the hole with dividers.

Dimensions should be made so complete as to make it unnecessary for the mechanic to make any additions or other calculations to find sizes.

The common fractions ½″, ¼″, ⅛″, 1/16″, 1/32″, 1/64″ are used where measurements are to be made with a rule. Decimals, such as 2.027″ or .375″, are employed when measurements are to be made with a more accurate instrument, such as the vernier micrometer.

No necessary dimensions should be omitted as it is never safe to permit a mechanic to take measurements from a drawing with a rule or scale.

Sources for further study:

Svensen: *Machine Drawing,* Chap. IV.

III. *The Problem*

To dimension at least two of the drawings which you have made.

IV. *Suggestions for Procedure*

1. Ask your instructor to return Problems 14 and 15.
2. Attach them to the board, and draw in all extension and dimension lines.
3. Put in arrowheads free-hand. Refer to Lesson 5.
4. Draw guide lines for figures to insure uniform size.
5. Place figures in their proper places, using single-stroke, free-hand Gothic numerals. Refer to Lesson 11.

Note: Do not copy the dimensions which are placed in circles in the book. These were put there for your convenience in locating the drawing on the sheet. Such dimensions are not ordinarily put in a drawing.

Note: Plate 16B illustrates how various methods of placing dimensions in a drawing are used. Note that the diameter of the pin is 1.25″ ± .005″. This means that the dimension is to be 1¼″ with an allowance ("tolerance") of not more than .005″ above or below this dimension.

Lesson 17

I. *Purpose*

1. To learn something about pulleys and belts used on machines.
2. To apply this knowledge and the principles of sections to the drawing of a pulley or handwheel.

II. *General Information: Pulleys and Belts*

Several common means are used for transmitting power from engines or motors to machines, such as saws or lathes. One of these is to mount the motor directly on the shaft of the machine. This is very convenient, but necessitates a separate motor for each machine, which is quite expensive. Another method is to use gears (wheels with teeth on them). These usually are noisy and are not satisfactory for high speeds unless they run in heavy oil. A third method is to use belts which travel over wheels called "pulleys."

Belts usually are made of leather and often of canvas or rubber fabric. Leather belts vary in thickness and width, depending on the number of horse power to be transmitted by them. Thicknesses are indicated by the number of ply; that is, we speak of single ply, three ply, etc. The width is expressed in inches.

Leather belts come from the best part of a cowhide; that is, a few inches on each side of the backbone. Long belts are made up of many short pieces glued together with tapered joints. The hair side of a leather belt is always turned toward the pulleys. This side of the leather will slip less than the flesh side.

Belts usually are flat, although some, used on small machines such as sewing machines, are round in section.

Belts may be endless, making a complete loop without a joint, or laced; that is, the ends are fastened together with a rawhide or wire lace, or with patented metal fasteners.

The pulleys are grooved for round belts; or flat, crowned, or flanged for flat belts. They usually are made of either wood or metal. Most wood pulleys are split and bolted together over the shaft. Small metal pulleys usually are solid, while the larger ones have arms to make them lighter.

A step or cone pulley is a combination of two or more pulleys of different diameters in order to permit shifting of the belt to get different speeds.

It is a common practice to use one large motor to drive a number of machines. In this case, the motor drives a long shaft attached to the ceiling. This is called a "line shaft." A shorter shaft, called a "countershaft," is placed above each machine. The countershaft is run by two belts com-

ing from pulleys on the line shaft. One of these belts is crossed, thus making its countershaft pulley revolve in reverse. By means of a clutch operated by a long wooden handle, it is possible to revolve the countershaft in either direction or to permit the pulleys to turn on it without revolving the shaft at all. The countershaft is connected with its machine or group of machines by means of a belt running on cone pulleys.

When one knows the speed of the motor, he can obtain practically any desired speed at a machine by choosing the proper sizes of pulleys. If two pulleys of different diameters are connected, the larger one makes fewer revolutions per minute (r.p.m.) than the smaller one.

For example, suppose a motor equipped with a 4″ pulley and having a speed of 1200 r.p.m. is to operate a line shaft at a speed of 300 r.p.m. What size (diameter) of pulley is needed on the line shaft? The problem is one of proportion in simple arithmetic. In general terms:

$$\frac{\text{r.p.m. of the drive pulley}}{\text{r.p.m. of the driven pulley}} = \frac{\text{Diameter of driven}}{\text{Diameter of drive}}$$

Solve the above problem. Answer: 16″ is the diameter of the line-shaft pulley.

A draftsman may obtain more detailed information about proper sizes and shapes of pulleys and the like from an engineer's handbook such as *Machinery Handbook.*

III. *The Problem*

To make a mechanical drawing of a pulley or a handwheel. Note how the arms are represented in the sectional views in Plates 17B and A. Where are handwheels used?

IV. *Suggestions for Procedure*

1. Lay out the front view first.
2. Note that the face of the pulley is crowned in Plate 17C and flat in Plate 17B.
3. In Plate 17C, why does it require three circles to represent the rim of the pulley?
4. In Plate 17B, note that the arms are not crosshatched in the sectional view.
5. In Plate 17A, observe that the arms are represented in the sectional view of the handwheel as if there were an even, instead of an odd, number of them. The center lines of these arms may be drawn with a 30° triangle.

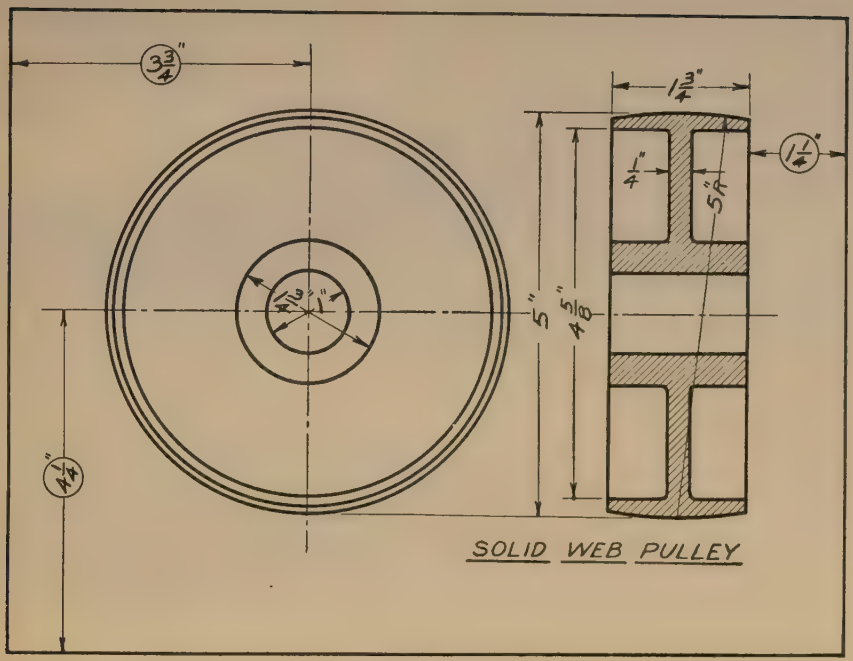


Plate 17C

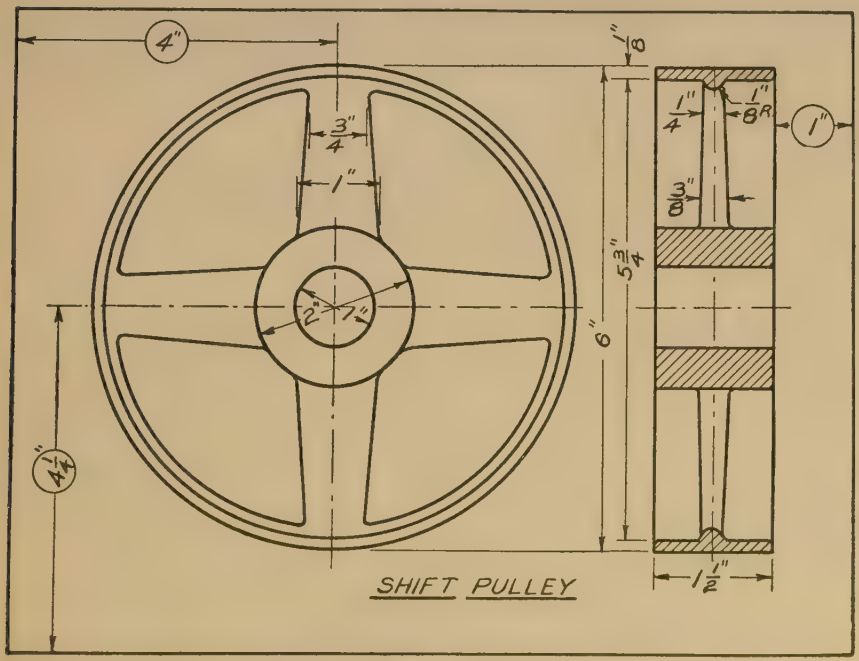


Plate 17B

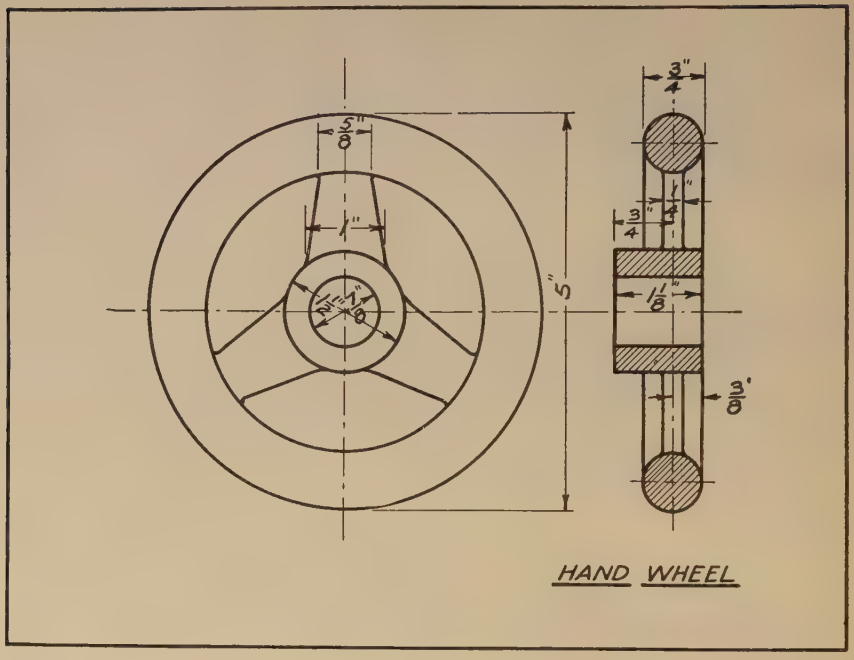


Plate 17A

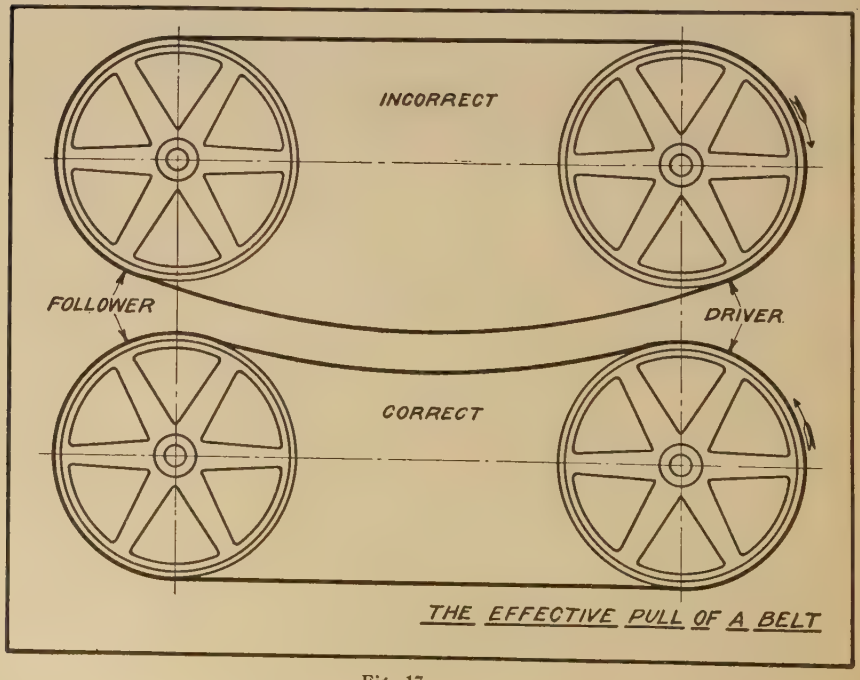


Fig. 17c

Lesson 18

I. *Purpose*

1. To learn the meaning and use of auxiliary views.
2. To make a drawing in which an auxiliary view is used.

II. *General Information: Auxiliary Views*

Sometimes the views commonly used to represent an object do not show its size and shape clearly. This is usually the case when one or more of the surfaces is a sloping one. In such cases, a view parallel with the sloping surface is drawn. Such a view is called an *auxiliary view*, meaning an extra or helping view. A study of Figure 18 and of Plates 18C, B, and A will make the method clear.

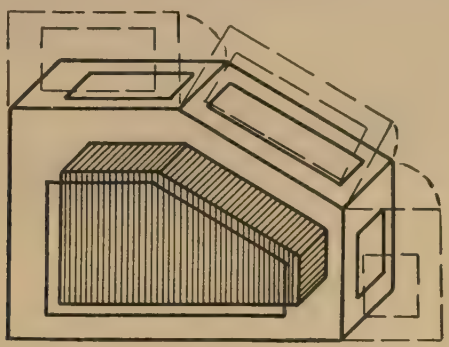


Fig. 18. Relationship of views when an auxiliary view is used

Frequently an auxiliary view will show only the sloping surface and omit other parts to be seen from that angle. Such is the case in Plate 18B. In other cases, the auxiliary view is made to show a complete view of all parts visible from the auxiliary plane, including some which will not appear in their true size and shape. The drawing in Plate 18A is an example of this.

The simplest way to understand an auxiliary view is to think of it as a view seen by looking straight against (at right angles to) the slanting surface. The dimensions of such a view are found from the regular views. In Figure 18 it will be seen that its width is the same as that of the top view, and its length is equal to that of the sloping line in the front view.

Sources for further study:

French: *Engineering Drawing*, pp. 81–85.

III. *The Problem*

To study the drawings which illustrate the use of auxiliary views, and to copy and complete one of these drawings. Note how the objects are more clearly shown by this method than if the regular views only were used. In Plate 18A, make an orthographic drawing with the necessary auxiliary view.

IV. *Suggestions for Procedure*

1. Draw as many of the regular views as seem necessary.
2. Project lines at right angles from the main points on the sloping surfaces.
3. Draw a center line parallel to the surface to be drawn, and at any convenient distance from it.
4. Lay out the auxiliary view on the center line mentioned above.

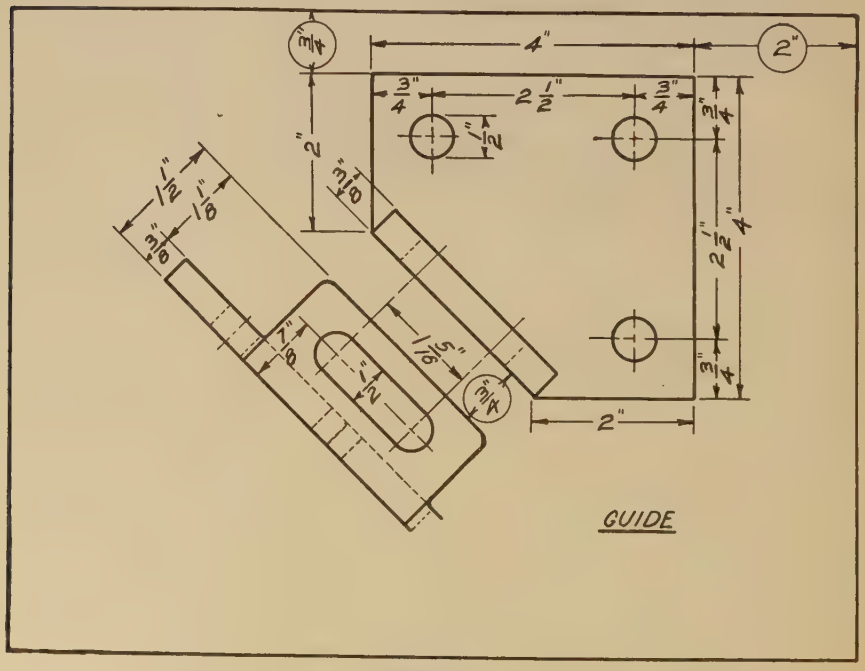


Plate 18C

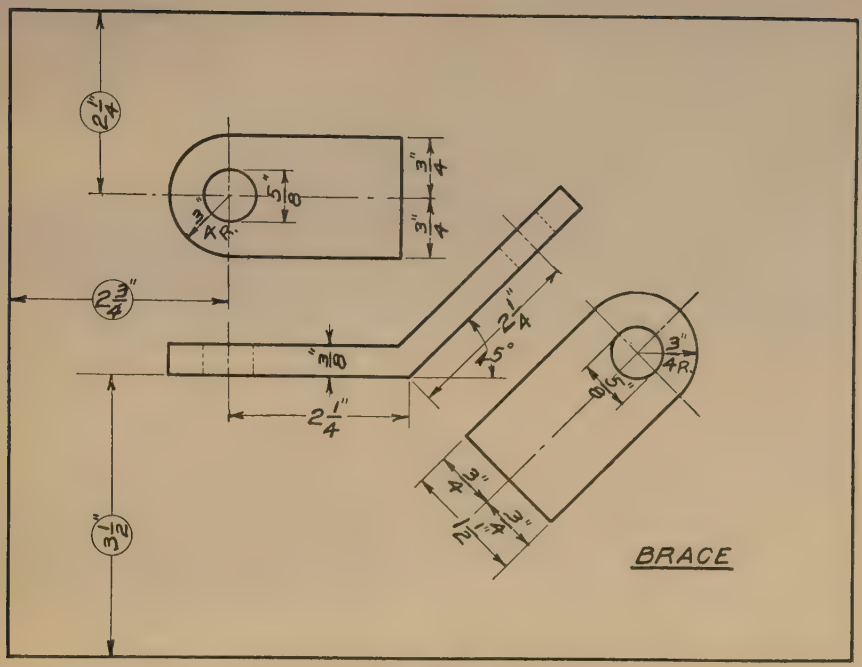


Plate 18B

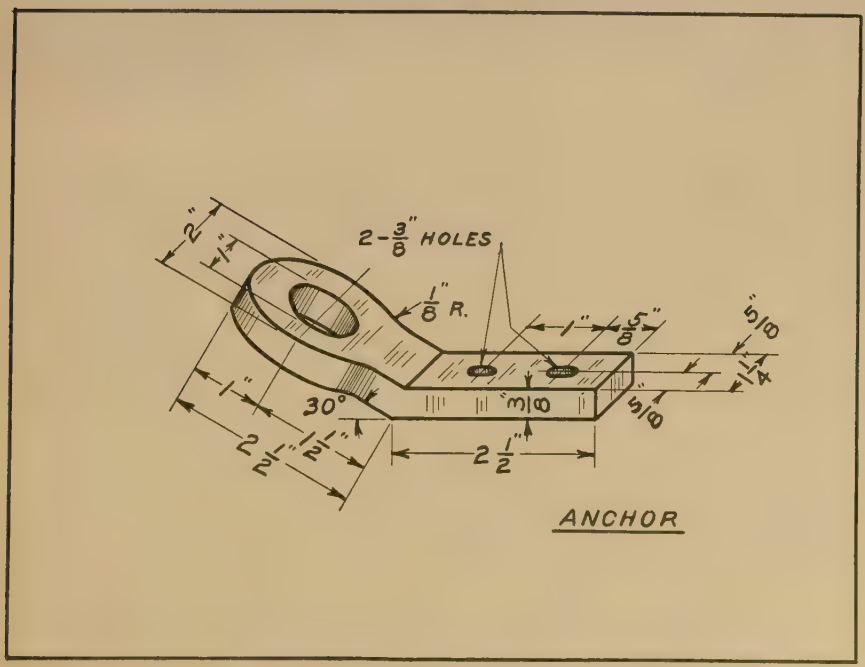


Plate 18A

Lesson 19

I. *Purpose*

1. To learn how large objects are represented on small sheets of paper; the meaning and use of scale; and broken and partial views.
2. To apply this knowledge in a drawing.

II. *General Information: Large Objects on Small Sheets*

All the drawings made thus far have been made full size. This is quite satisfactory when the objects represented are small. A full-size drawing of an automobile, a locomotive, or a house would not only be difficult and impractical to make, but would be of little value, as the sheet would be so large that all of it could not be seen at one time.

The usual procedure in such cases is to draw the object to a reduced scale; that is, the drawing shows the true proportions of the object, but is smaller. Sometimes drawings are made larger than the object in the same way. For example, the drawing of the balance wheel of a watch would be made several times larger than the wheel itself.

If a drawing is to be made at one-half scale, each inch of the object is made ½″ on the drawing. This shows the object clearly as to shape, and as the dimensions lettered in the drawing are those of the object regardless of the size of the drawing, the true size is shown as well. Always put the actual dimensions of the object in the drawing regardless of the scale used.

Drawings are made at even fractions of the size of the object (½, ¼, ⅛, ⅜, ¾, etc.), never at odd scales such as 1/3, 1/5, etc. In drawings of large buildings, the scale is often as small as ⅛″=1′, which is only 1/96 actual size.

On a regular draftsman's scale, different edges are marked off for the various scales. These are merely rules on which the inches are reduced in size. This is very convenient, since by such an arrangement all one has to do is to select the desired scale and proceed as when making full-size drawings.

Sometimes parts of an object are drawn to a larger scale than is used on other parts. This is done where a small-scale drawing would make some complicated parts confusing to read. These large-scale drawings of parts are called "detail drawings" or simply "details."

Other methods of getting the drawing of a large object on a small sheet also are used. One of these is to draw only one half or one fourth of the whole object where the other parts are the same. (See Plate 19A.) Another method is to show part of the object broken away. Plate 19C

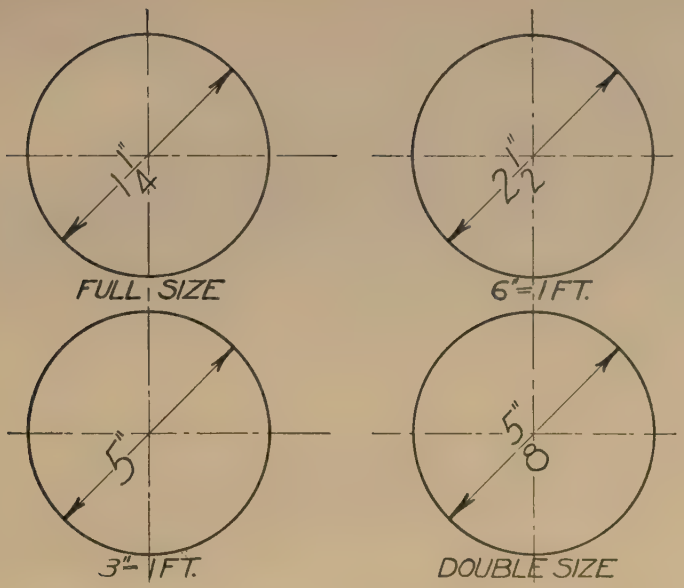


Fig. 18a. These four circles are drawn the same size but represent circles of different sizes as indicated by the dimensions

shows the middle of the shaft broken out, which merely indicates that the shaft was too long to conveniently draw on the paper. Its actual length is shown by the dimension, however. Irregular free-hand lines are often used to indicate a "break." Sometimes only a portion of a continuing part is drawn, and its actual length indicated by a note. For example, one might draw only one section of a bridge railing, and show with a lettered note that the railing is to continue to a total length of, let us say, 156′–8″.

Sources for further study:

French: *Engineering Drawing,* pp. 9–27.

III. *The Problem*

To reproduce one of the following drawings or make a similar drawing of an object assigned by the instructor. In addition, make a quick free-hand cabinet sketch of the Crank in Plate 19A, showing the whole object.

IV. *Suggestions for Procedure*

1. Try to visualize in each case how the actual object appears.
2. In making the free-hand cabinet sketch, refer back to Lessons 9 and 13.

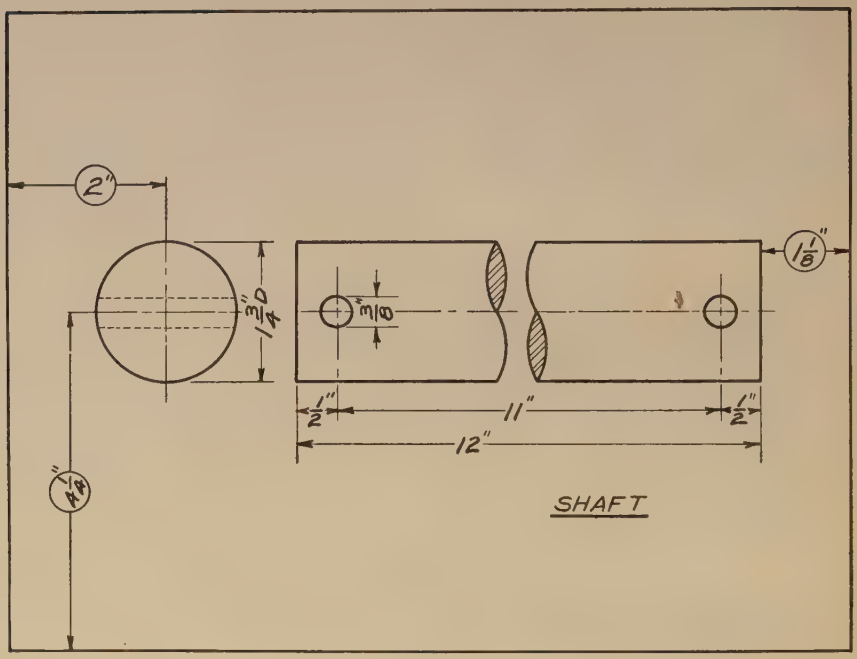


Plate 19C

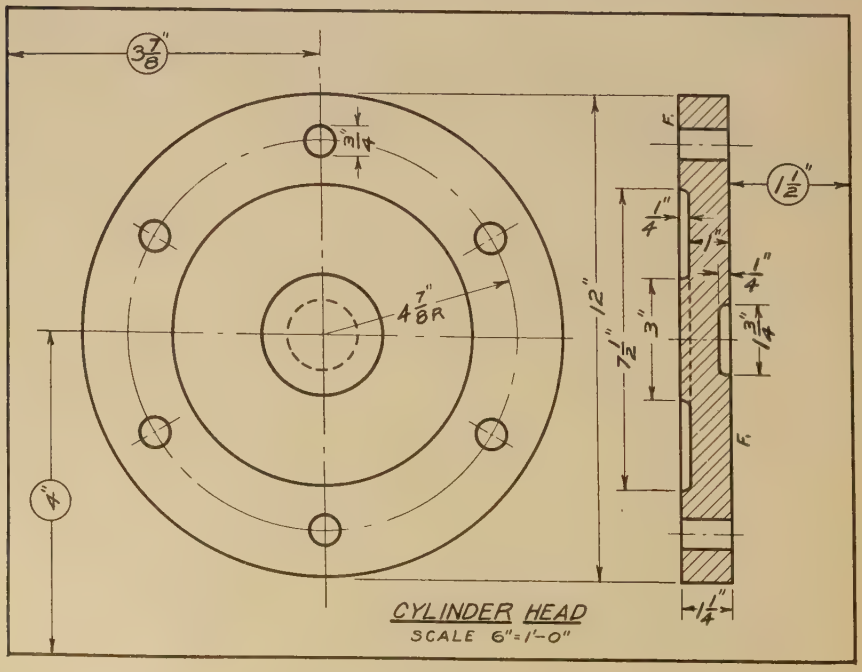


Plate 19B

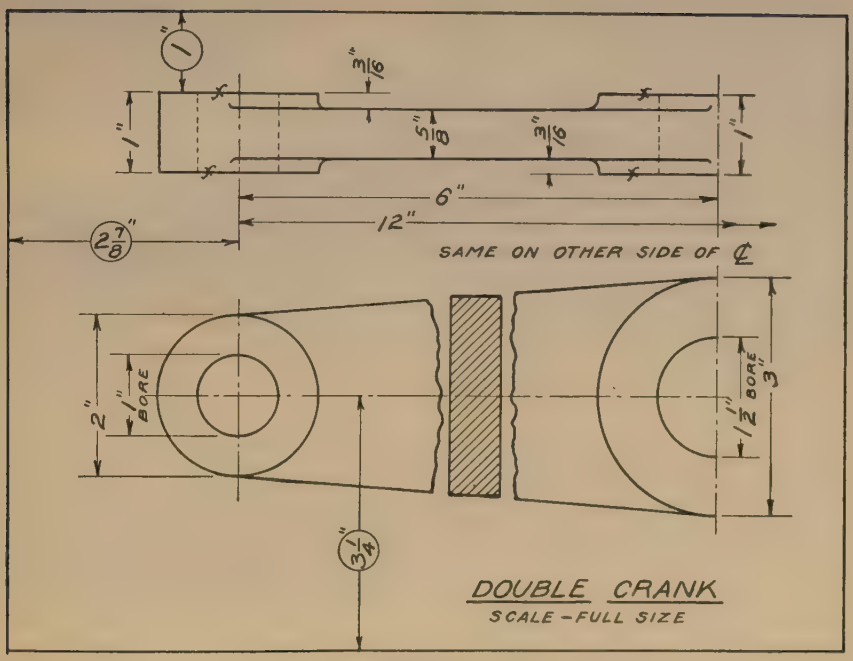


Plate 19A

3. In Plate 19C, the radius of the arcs used in the curve which shows the break usually is made equal to one half the diameter of the shaft. This curve may be drawn free-hand if desired.

4. The letter F or the mark *f* on a surface indicates that it is to be finished, that is, made smooth.

5. The word "BORE" in Plate 19A indicates that the hole is to be bored.

6. In Plate 19A, also note the revolved section which makes the shape of the crank more clear.

Geometric Constructions

Much of mechanical drawing is applied geometry. In the plates on page 75 are eight geometric constructions commonly used by draftsmen in connection with drawings of real things. These are quite simple and are explained in detail in the paragraphs which follow.

To bisect a line, set the compass at any convenient radius greater than one half the length of the line. Using the ends of the line as centers, describe the arcs as indicated in the drawing. Connect the points of intersection of the arcs with a straight line. If the work has been accurately done, this line will cut the original line in exactly two equal parts.

To bisect an angle. The same principle is used here as in bisecting a line. The drawing should be self-explanatory.

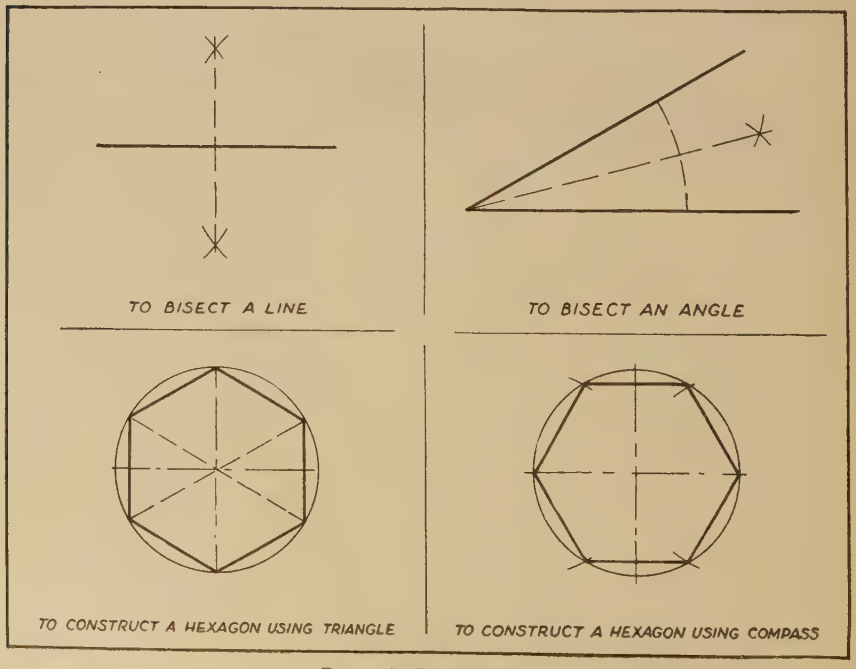
To construct a hexagon using a 30°–60° triangle. Draw a circle of the desired size. Through its center, draw a vertical and two 30° lines. These lines will cut the circumference at six points, so that when they are connected with straight lines the result is a regular hexagon which has six equal sides and six equal angles.

To construct a hexagon using a compass. Draw the circle as in the foregoing. With the compass still set at the radius of this circle, take six steps around the circumference. These will come out even and, hence, locate the corners of the hexagon.

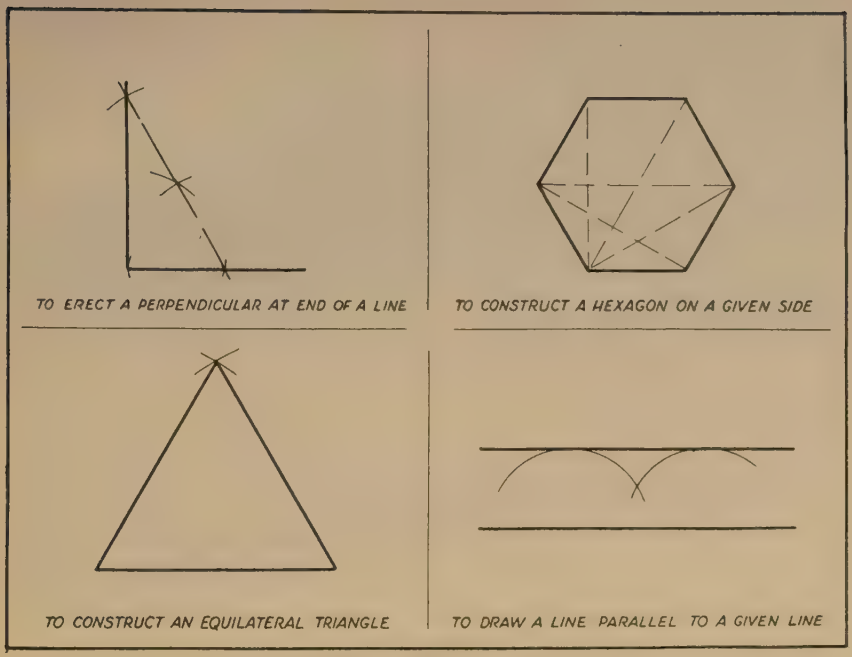
To erect a perpendicular at the end of a line. Mark off any convenient distance from the end of the line. With this distance as a radius and the ends of the distance as centers, describe the two intersecting arcs shown. With this point of intersection as a center, draw the remaining arc as indicated. Draw the sloping line and then the perpendicular.

To construct a hexagon on a given side. Here the length of one side is the only information given. The method will be apparent to the student, if he observes that all sloping lines in this drawing are either 30° or 60°.

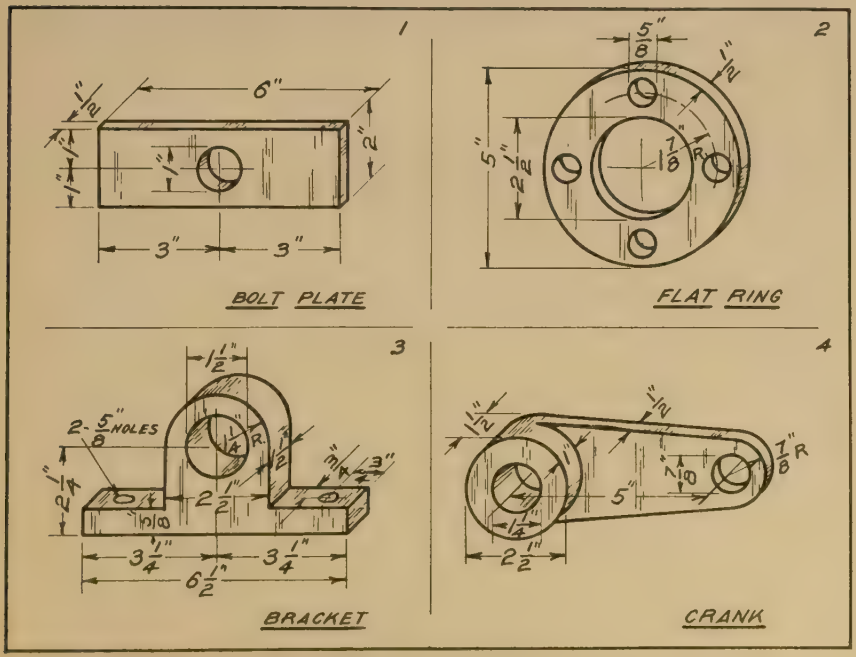
The two remaining constructions are simple enough to be self-explanatory.



Geometric Constructions


TO ERECT A PERPENDICULAR AT END OF A LINE
TO CONSTRUCT A HEXAGON ON A GIVEN SIDE
TO CONSTRUCT AN EQUILATERAL TRIANGLE
TO DRAW A LINE PARALLEL TO A GIVEN LINE

Geometric Constructions



Suggestive Test 2. Make three-view drawings of the objects shown above

Lesson 20

I. *Purpose*

1. To learn something about standard and interchangeable parts in modern machine industries, and especially to gain an understanding of standard bolts, nuts, and threads.

2. To apply this knowledge to the drawing of a common machine bolt or screw thread.

II. *General Information: Standard and Interchangeable Machine Parts*

Have you ever asked yourself the reason why a tailor-made suit costs more than the same suit ready-made, or why we get more for $100 in a factory-made automobile than we do for a similar amount in a house? The reason is that, in the case of the ready-made suit or the car, a great many parts are made exactly alike and are produced by machines instead of men using hand tools. This calls for what is known as the "standardization of parts." A given part of a car, for example, is not only interchangeable with the same part in other cars of the same make, but many of the more common parts, such as bolts, pipe, gears, etc., are often interchangeable in machines of other kinds and makes as well.

President Hoover, while in the position of Secretary of Commerce, was responsible for encouraging and improving much of this type of standardization. His efforts affected not only the products of the machine industries, but such things as building materials, paints, printers' paper, foodstuffs, chemicals, and many other items too numerous to mention. This standardization is one of the most fruitful means of eliminating waste in industry, and we may expect more and more of it as time goes on.

One of the most common examples of standard parts are common bolts and screw threads. Bolts are used to fasten parts of a machine together, when it may be desirable to take them apart again for replacement or repair. Rivets are used for fastening parts permanently. Rivets will be discussed in a later lesson.

Many kinds of bolts are in use for different purposes. For example, there are machine bolts, carriage bolts, stove bolts, setscrews, stud bolts, cap screws, etc. The most common of these is the machine bolt. It is like those shown in Plates 20C and 20B. Several standard types of machine bolts are in use at the present time. The National Standard, formerly

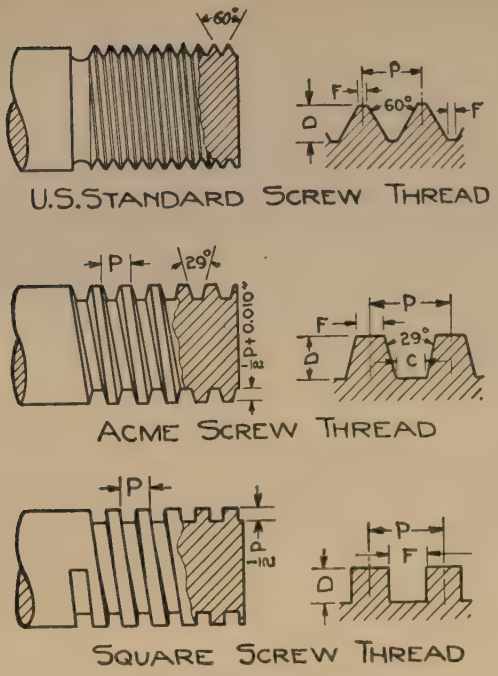


Fig. 19. Common standard thread forms

known as the United States Standard, abbreviated U.S.S., is the most widely used. Another machine bolt used a great deal, especially in automobile manufacture, is the S.A.E. standard. S.A.E. stands for Society of Automotive Engineers.

The size of the threads on a bolt of a certain diameter is determined by the standard, and is expressed in terms of the number of threads to the inch. S.A.E. bolts have more threads to the inch than the U.S.S. For example, a ½" S.A.E. bolt has 20 threads to the inch, while a ½" U.S.S. has only 13.

The diameter of a bolt is that of the rod from which it was made. The length is measured from under the head to the extreme end of the thread. To specify a certain bolt then, one must give (1) kind of bolt, (2) the standard desired, (3) the diameter, (4) the length.

In drawing threads, the actual curved shape is seldom used, because it is too difficult to draw accurately. Instead, we use one of the several straight-line conventional methods shown in Plates 20B and A.

Sources for further study:

Svensen: *Machine Drawing,* Chap. II.

III. *The Problem*

To study the methods of representing threads and bolts, and to make a mechanical drawing like one of those shown.

IV. *Suggestions for Procedure*

1. Locate and draw center lines.

2. Make the end views of the bolts before laying out the side views of the heads.

3. In Plate 20C, the lines representing the roots of the threads in the thread convention should be drawn approximately $\frac{1}{8}$" inside the outline of the bolt.

4. In Plate 20B space the threads $\frac{1}{8}$". Use a very sharp hard pencil. Work on the center line. Do not include the 60° dimension on the finished drawing. A 1" radius is used to draw the arc at the end of the bolt. The slope of the lines will be one half of the pitch of the thread. In this case 1/16". The 30–60° triangle is used in constructing the hexagon which represents the bolt head.

5. In Plate 20A there are 8 threads to the inch except in the case of the square threads in which there are 4 threads to the inch.

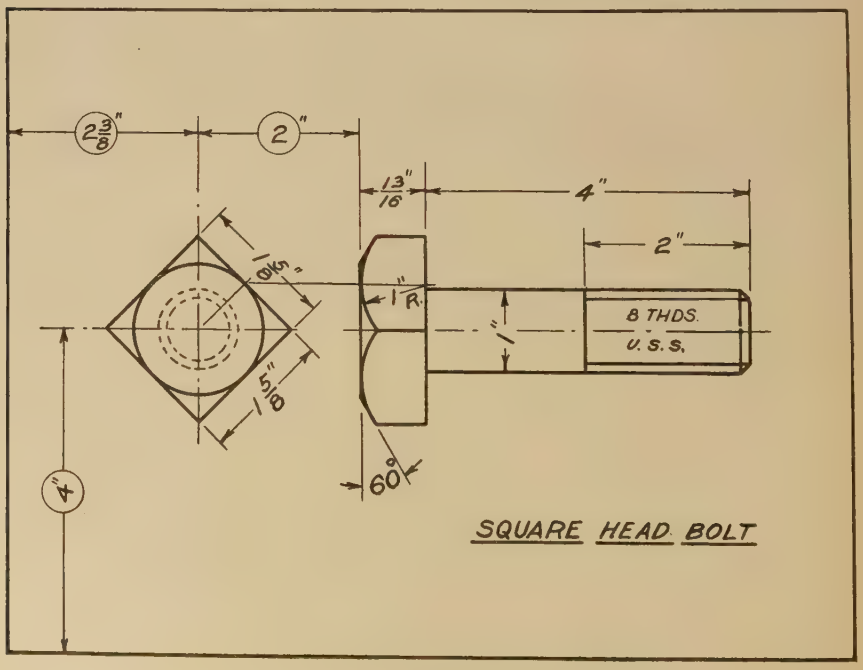


Plate 20C

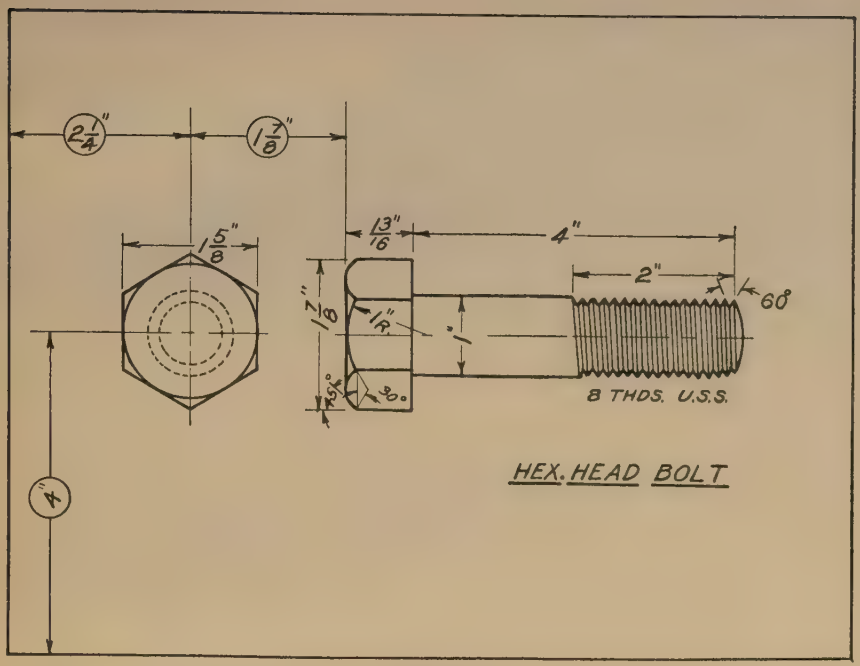


Plate 20B

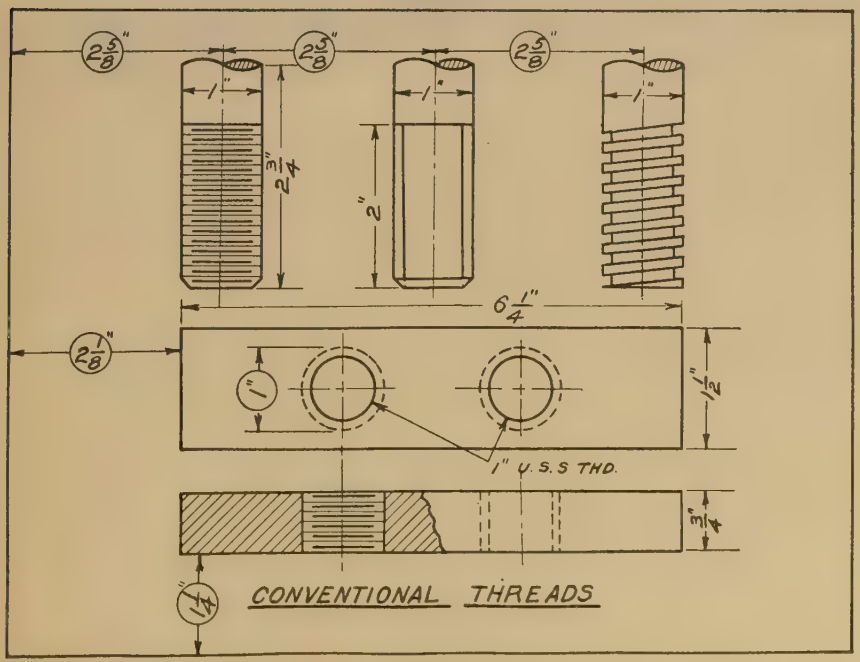


Plate 20A

Lesson 21

I. *Purpose*

1. To learn something about the uses and kinds of gears.
2. To learn how to represent common gears in a drawing.

II. *General Information: Gears*

Gears are wheels with teeth. They are mounted on shafts, and the teeth are meshed with each other in some definite way in order to obtain a desired result as explained below. When power is applied to one shaft, it is transmitted through the gears to the other shafts in the system. Several gears meshed together are referred to as a "train" of gears. The smallest gear in a train is called a "pinion."

As compared with belts and pulleys, gears have the advantage of eliminating slipping. They also require less space. For example, it would be hard to imagine the use of belts and pulleys in the transmission of an automobile.

In general, gears may be used for one or more of four common purposes. One is to obtain a desired *speed,* as when using the "high" gears in an automobile. Another is to obtain *power,* as in the case of using the "low gears." Still another is to produce a desired *direction of rotation* in a shaft, as when using the reverse gears in a car. And finally, gears are used to *change the direction of the axis* of rotating shafts. For example, gears are used to transmit power and motion from the drive shaft of a car to the rear axle which is at right angles to it.

Gear teeth are standardized in much the same way as screw threads. The shape of the teeth is very important in order to prevent excessive wear and noisy operation. The wearing surfaces of the teeth usually are in form of an involute or spiral curve.

Gear ratio means the arithmetical relationship between the number of teeth on the drive gear and on the driven gear. For example, if the drive gear has 18 teeth and the driven 36, the ratio is 1 to 2. The driven gear in this case will revolve only one half as fast as the drive.

There are many kinds of gears and gear combinations. The machine draftsman must be able to design and use all of these in their proper places.

One of the most interesting combinations of gears is that found in the differential of an automobile, which permits motion to be transmitted

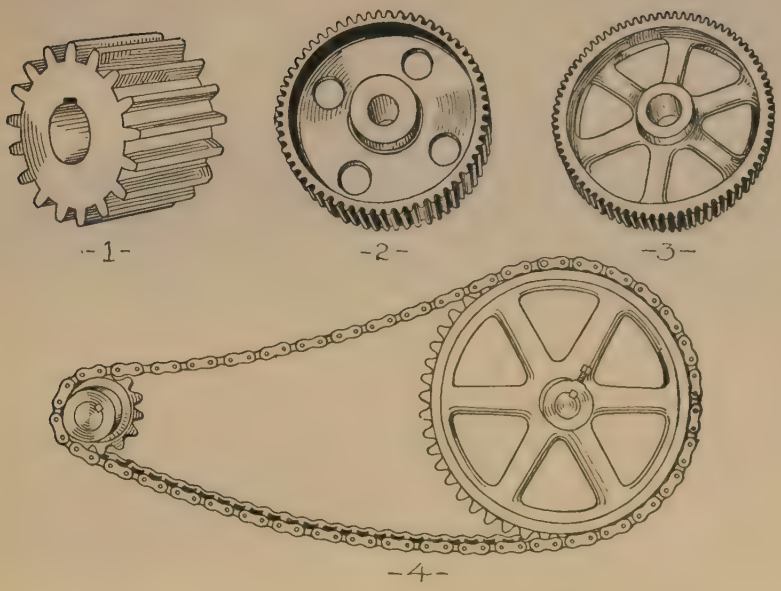


Fig. 19a. Three types of spur gears and a link belt with sprocket wheels. 1. Solid gear; 2. web gear; 3. gear with arms; 4. link belt with sprocket wheels

to both rear wheels, but at the same time allows them to revolve at different speeds as the car rounds a corner.

A draftsman seldom draws the teeth of a gear, but represents them in a conventional way, as shown in Plates 21C and 21B. Note that the teeth are not crosshatched in the sectional view. The letters P.D. stand for pitch diameter, which is the diameter of the pitch circle. This is an imaginary line drawn approximately midway between the outside ends and the roots of the teeth. All calculations in gear design are made on this circle. O.D. means outside diameter, and R.D. indicates root diameter. C.P. is for circular pitch, which is the distance from the center of one tooth to the center of the next, measured on the pitch circle. D.P. is for diametral pitch, which is the number of teeth to each inch of diameter in the pitch circle.

Gear design in all its variations is worthy of the life study of a mechanical engineer. The foregoing information is intended only to make the student aware of the possibilities in this field.

Sources for further study:

French: *Engineering Drawing*, pp. 201–204.

III. *The Problem*

To study Plates 21C, B, and A in the light of the foregoing information, and to reproduce one of them.

IV. *Suggestions for Procedure*

1. Note that the outside circle and the root circle are represented by extension lines, while the pitch circle is shown by a dot-and-dash line.

2. The decimals in the dimensions are for the machinist's use. In drawing, such accuracy is impossible. In this drawing, the decimals may be reduced to the nearest sixteenth in common fractions. For example, 4.35″ is about equivalent to 4⅜″, and 3.92″ approximates 3 15/16″.

3. In Plate 21A a method is suggested for drawing the teeth with a compass. It should be remembered that this is only an approximation of the true shape of the teeth. The centers of the arcs representing the faces of the teeth are located on the base circle (B.C.), the radius of which is 2.46″ in this case. These arcs extend from the B.C. to the outer end of the teeth. The lines from the B.C. to the root circle are straight lines running toward the center of the gear. The width of the teeth and spaces is ½″ measured on the pitch circle. The outlines of the teeth may be drawn free-hand, if desired.

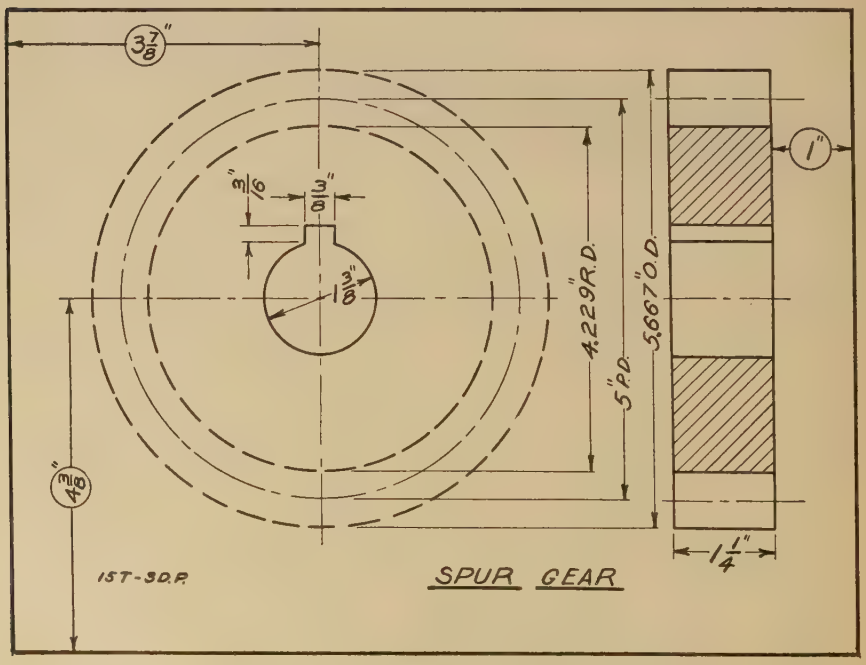


Plate 21C

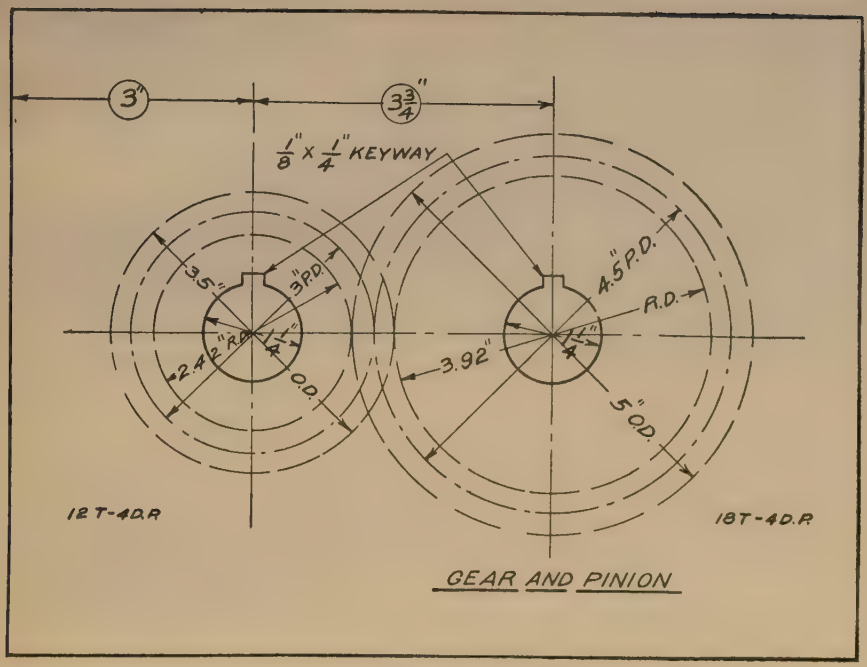


Plate 21B

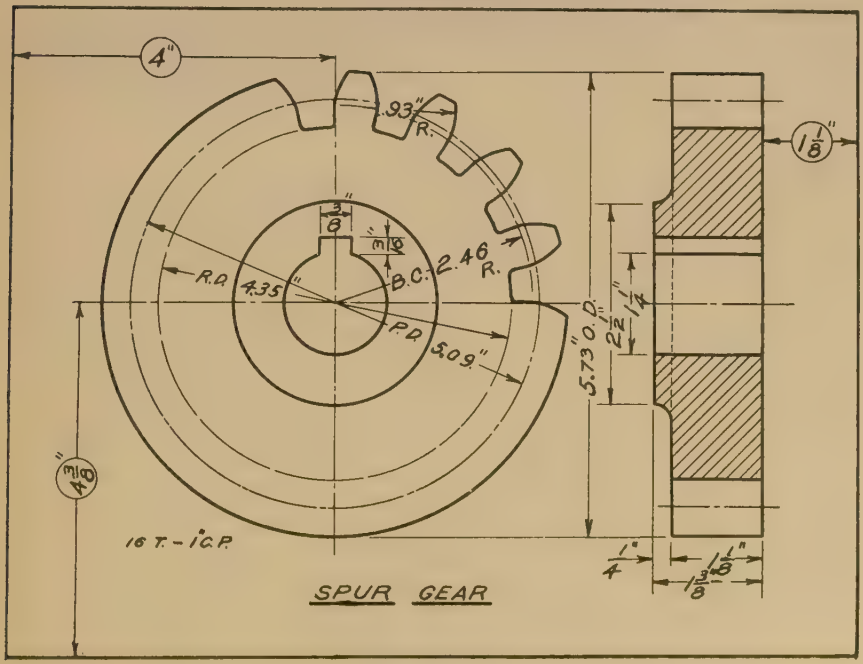


Plate 21A

Lesson 22

I. *Purpose*

1. To learn about cams and their use in machines.
2. To draw a simple cam.
3. To become familiar with the use of notes in drawings.

II. *General Information: Cams and Cam Motion*

The motion produced by an electric motor, a gas or steam engine, or a turbine, is always rotary. Frequently it is necessary to transform this rotating motion into one that is sliding or rocking. Usually this effect is produced by mounting specially shaped plates on rotating shafts. A rider or lever of some kind is made to follow the motion of the revolving plate. Such a plate is called a "cam." The ordinary exhaust and intake valves of an automobile engine are opened at the correct time by such cams. An eccentric cam is a circular plate mounted off center on its shaft. See Plate 22C.

The arm which guides the thread in winding the bobbin of a sewing machine is moved by a heart-shaped cam. Cams are used a great deal in printing presses, typesetting machines, bottle-making machines, power looms, and so forth.

It should be noted that cams are seldom used to transmit any great amount of power. Their chief uses are in tripping levers, moving arms, opening valves, and work of similar kinds which requires a special motion, but little power.

The ability to design a cam which will produce any kind of motion desired should be a part of a machine draftsman's "stock in trade."

Sources for further study:

Svensen: *Machine Drawing*, pp. 120–125.

Use of "Notes" in Drawings. The student has, no doubt, taken note of the fact that in many of the drawings which he has made or studied, lettered information is given in addition to lines and dimensions. These notations are called *Notes*. In machine work, a drawing should give all the information necessary to make the object. Brief notes are often very effective in providing information about materials, number of parts wanted, finish to be applied, and matters of a similar nature, which are not apparent from the drawing itself.

Some examples of notes commonly seen in drawings follow:

Make 20 M.S., meaning to make 20 pieces of machine steel.

20 Req. (required) or *20 wanted.*
Caseharden after finishing.
Turn to 2.378 inches, and grind to 2.375 inches.
Drill in place with shaft.
Give finished piece one coat red lead paint and one coat black japan.
File to smooth surface.
Polish and nickel plate.
All parts to have blue finish.
Length of rod before bending 20".
Fit to 6" I Beam.
Bend hook to fit over Bar A.
Bolt part A to part B before grinding.

Names of materials are often abbreviated as:

Abbreviations Used in Mechanical Drawings

Bab.	babbitt	R. *or* Rad.	radius
Bz.	bronze	Thds.	threads
Br.	brass	C. P.	circular pitch
Ph. Br.	phosphor bronze	D. P.	diametral pitch
Cop.	copper	P. D.	pitch diameter
C. I.	cast iron	Thds. per in.	threads per inch
M. I.	malleable iron	F or *f*	finish
W. I.	wrought iron	R. P. M.	revolutions per minute
C. R. S.	cold-rolled steel	mm.	millimeters
T. S.	tool steel	U. S. S.	United States standard
M. S.	machine steel	A. W. G.	American wire gauge (Brown & Sharpe)
G. I.	galvanized iron		
C. S.	cast steel	Hd.	head
S. C.	steel castings	C. to C.	center to center
S. Forg.	steel forging	Sq.	square
S. Tube	steel tubing	Hex.	hexagonal
ft. *or* ′	feet	Oct.	octagonal
in. *or* ″	inch	L. H.	left hand
° *or* deg.	degrees	R. H.	right hand
±	plus or minus	Scr.	screw
D., dia., *or* diam.	diameter	Std.	standard
T	turn	F. A. O.	finish all over

It may be seen from the nature of the above notes that the draftsman must be thoroughly familiar with the work of the shop in order to do his work intelligently.

In Plate 22C in this lesson, the letter "T" following the dimension indicates that the cam is to be cast somewhat larger than the dimension and *turned down* to size in the lathe. The letter "F" indicates that the surface upon which the letter is placed is to be finished; that is, machined smooth instead of left rough as it comes from the foundry.

III. *The Problem*

To make a mechanical drawing of one of the cams shown in Plates 22C, B, and A. Try to visualize how a follower would be moved by the rotation of the cams.

IV. *Suggestions for Procedure*

1. Plate 22C is to be copied.
2. Plate 22B should be copied with the top view added.
3. Plate 22A. Draw the base circle, using a radius of 1¼". Divide the circle into 12 equal parts, using the triangles. Draw six other circles each ¼" larger than the preceding one. Lay out the points on the outline of the cam as suggested in the drawing. Connect these points with a free-hand curve or use a French curve.

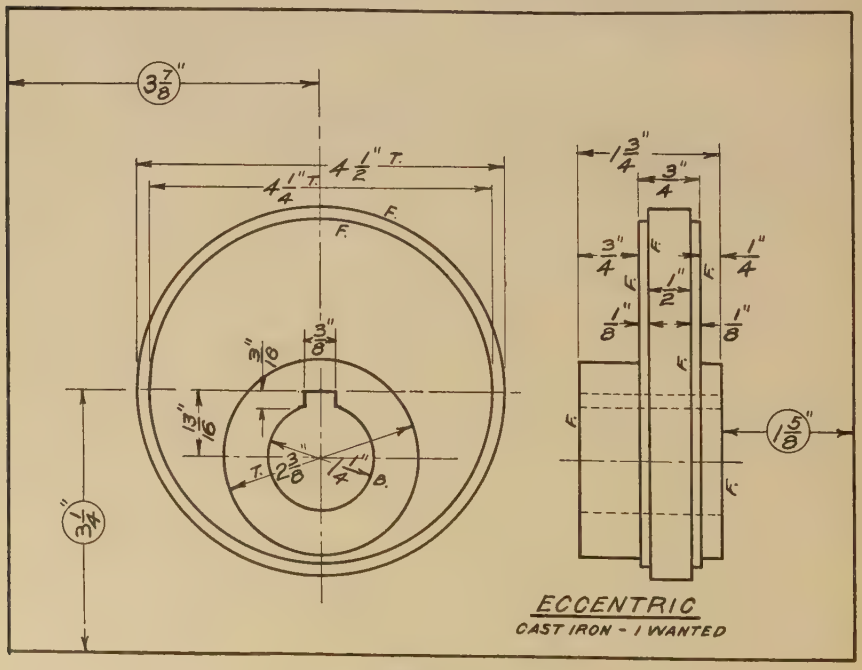


Plate 22C

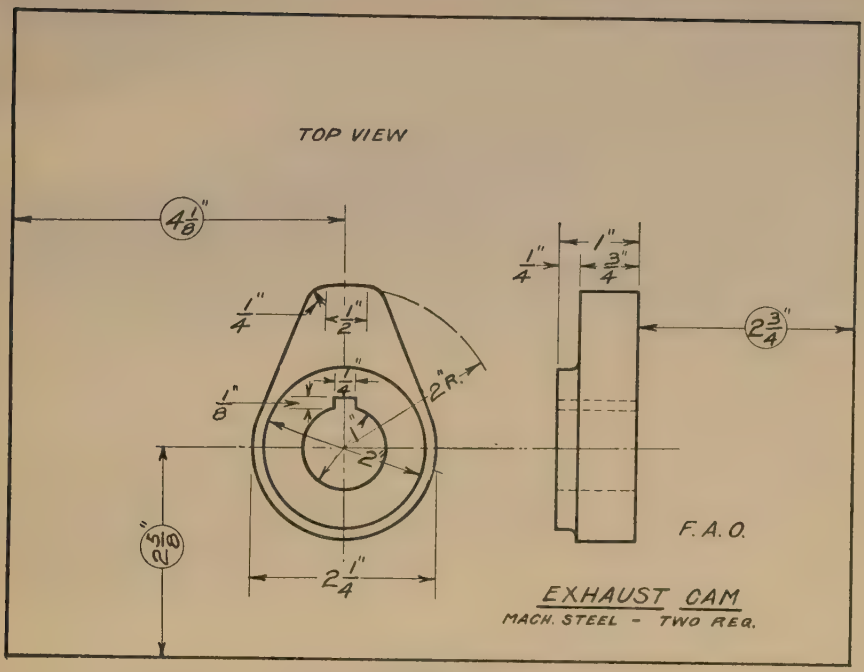


Plate 22B

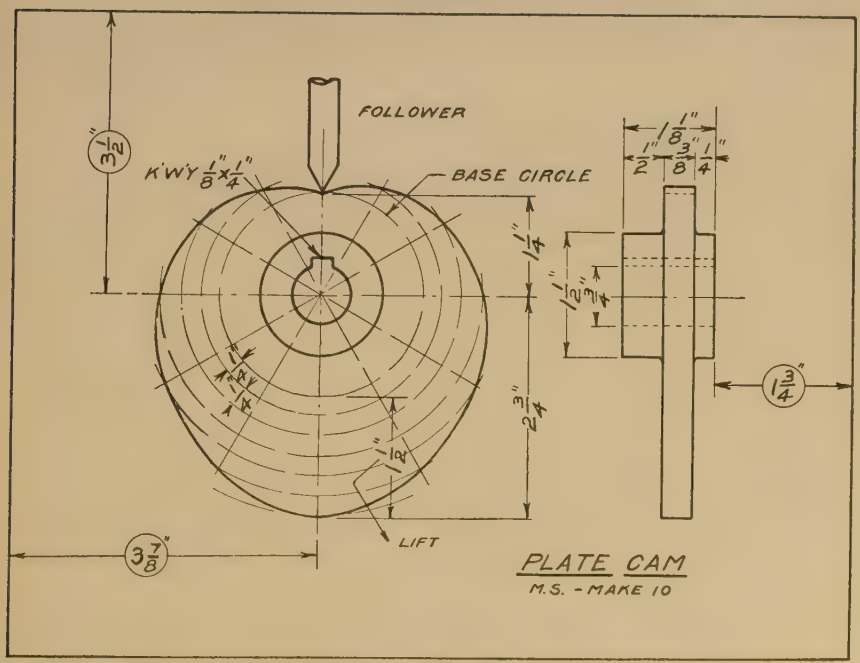


Plate 22A

Lesson 23

I. *Purpose*

1. To acquire some knowledge of the methods used in forging and machining metals.

2. To make an orthographic drawing of a machine part, working from a pictorial drawing or a model.

II. *General Information: Forging and Heat Treatment of Iron and Steel*

The blacksmith working at his anvil before an open forge was the original metal worker. With the coming of modern factory methods the blacksmith shop has all but disappeared, and where it remains, its chief business is the repairing of farm machinery and similar work.

The modern treatment of iron and steel involves and requires the use of chemistry, a knowledge of the properties and uses of many new alloys, and the application of the science of metalography, besides a knowledge of the many thousands of special uses to which these metals are put. The writer recalls a high-school boy who, being handy at making things, attempted to make a jackknife blade by forging it out of a 20d spike. Needless to say, the blade would not cut any but the very softest materials. He little realized the great amount of knowledge and skill which goes into the making of steels for different purposes. Nails, railroad rails, razors, watch hairsprings, hammers, saws, cutters for machine tools, and springs for automobiles are all made of steel, but each has special properties fitting it for its particular job.

Men who deal with matters such as those described in the foregoing are called "metallurgical engineers."

Steel is *hardened* by heating it to a red color and cooling it quickly in water or oil. It is *tempered* by reheating it until the desired degree of hardness is obtained, and cooling it quickly at that point. *Annealing* is the process of softening steel by allowing it to cool very slowly. Most of the heating is done in gas or electric furnaces instead of the old, open, coal forges. Very little forming and shaping is done by hand. Pieces that formerly took a blacksmith hours to forge by hand are now stamped out in one blow by a huge drop hammer operated by power machinery. The specially shaped forms which stamp the red-hot pieces to the proper shape are called "dies."

Casehardening is the process of hardening the exterior of a steel object, such as a wrench, so as to produce a good wearing surface and at the same time retain the toughness of the softer steel.

Oxyacetylene welding is another new and interesting development in the field of metallurgy.

The machine draftsman must be familiar with metals and how they are worked, in order to make intelligent drawings of things involving their use.

Machine-Shop Practice

The final operations in the manufacture of a machine are performed in a machine shop or a factory department corresponding to it.

The increasing use of machines, and the tendency to use metals in the manufacture of things formerly made of other materials, have greatly increased the importance of machine-shop work. Many of our great manufacturing industries, such as the automobile, airplane, and locomotive enterprises, are really huge machine shops.

A knowledge of work of this kind is essential to the machine draftsman. He should know which machines are used for each operation and the limitations and advantages of each. Castings and forgings are smoothed to a finished surface, and cut to accurate dimensions by filing, planing, milling, turning, shaping, and grinding. Cylindrical shapes are turned on a lathe. (Fig. 20.) A milling machine is used for cutting gear teeth, mak-

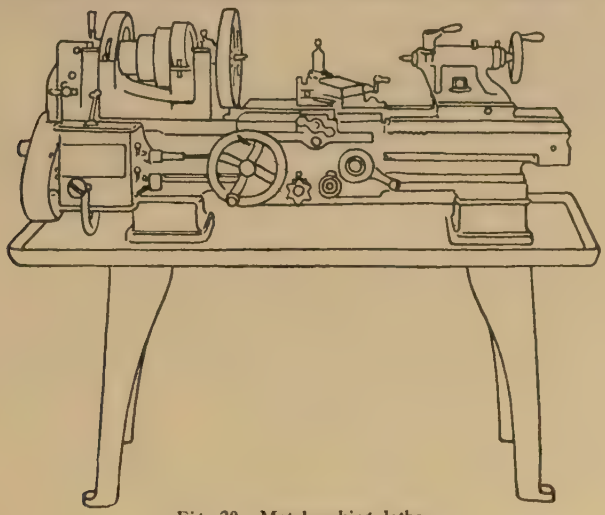


Fig. 20. Metalworking lathe

ing slots, etc. A shaper is used for cutting irregular shapes. The grinder is used for producing the final finish on shaft journals, motor pistons, and the like. The drill press is used for drilling holes.

Many of these machines are automatic or semiautomatic, and do most of the work, requiring the operator to do nothing more than set the machine and feed in the materials. For example, drill presses which will bore 15 or 20 holes of various sizes and in any location desired, all in one operation, are in use. Some machines make bolts automatically just by

setting the machine and feeding rod stock into a hole in the shaft. Besides these, many other machines are made for special purposes, such as bending machines, stamping machines, nibblers, etc.

The use of improved machines in modern factories has made it possible to employ workmen with little skill or experience. This places an added responsibility upon the draftsman, who must make his drawings unusually clear and definite, as little or nothing can be left to the judgment of such workers.

Sources for further study:

Machinery Magazine, Industrial Press, New York.
Textbooks on machine-shop practice.
Visit a machine shop or factory.

III. *The Problem*

To study the pictorial drawings in Plates 23C, B, and A, and make a 2- or 3-view drawing of one of them. Of what kind of material would each of these objects probably be made?

IV. *Suggestions for Procedure*

The student should be able to make these drawings without further suggestions.

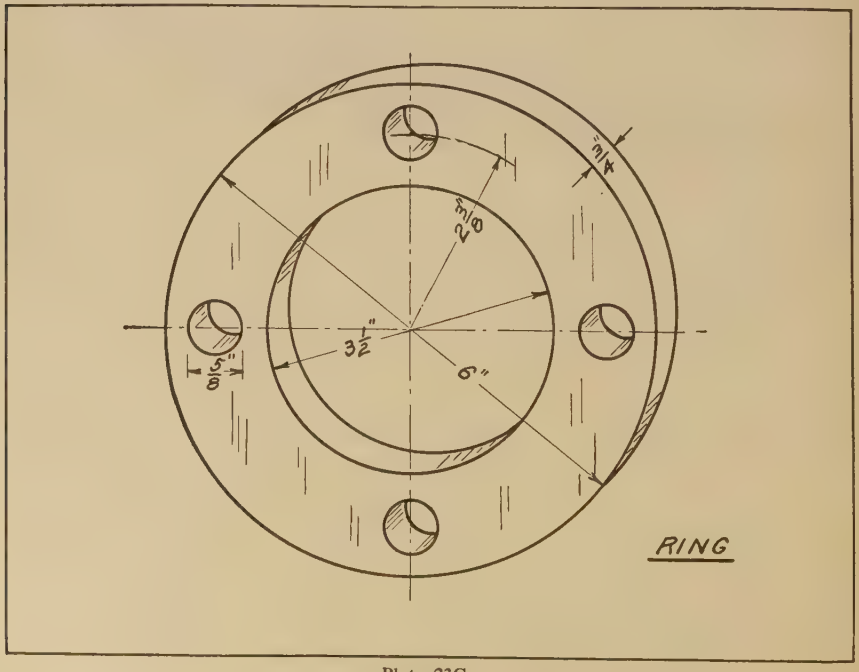


Plate 23C

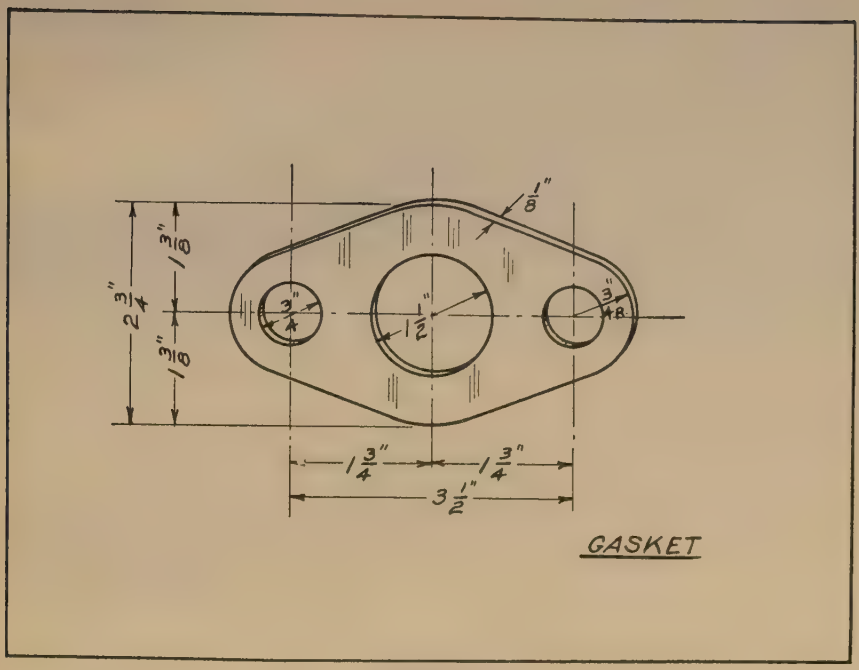


Plate 23B

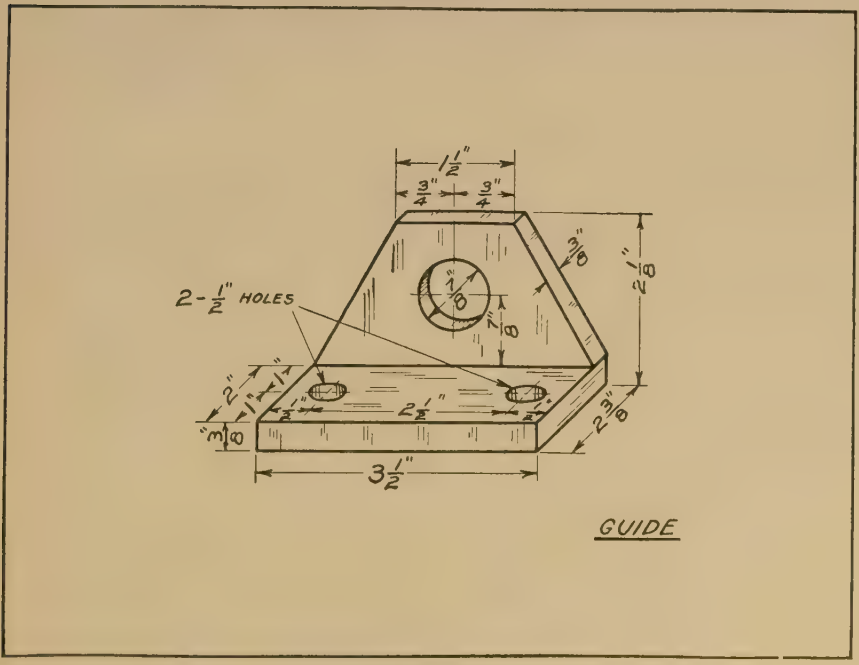
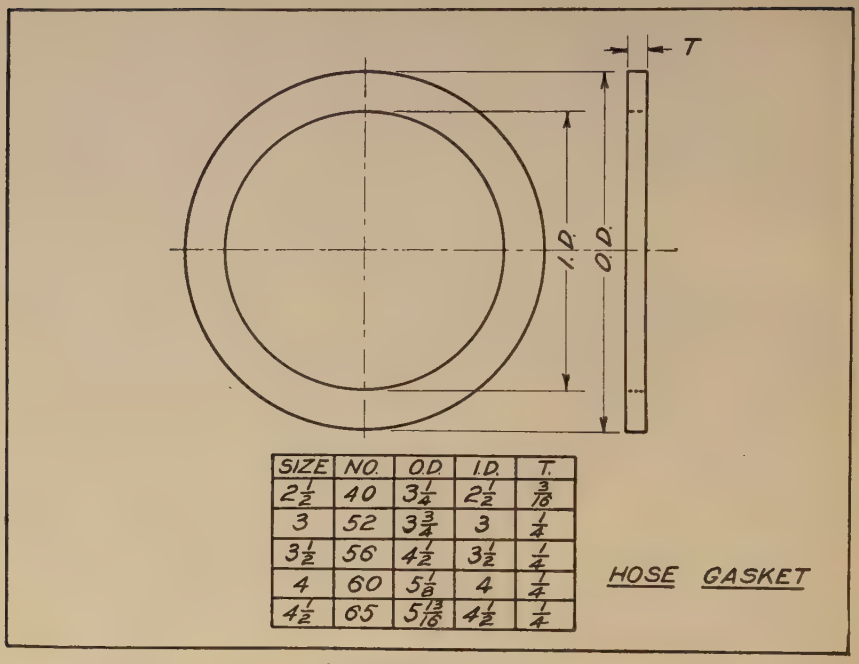


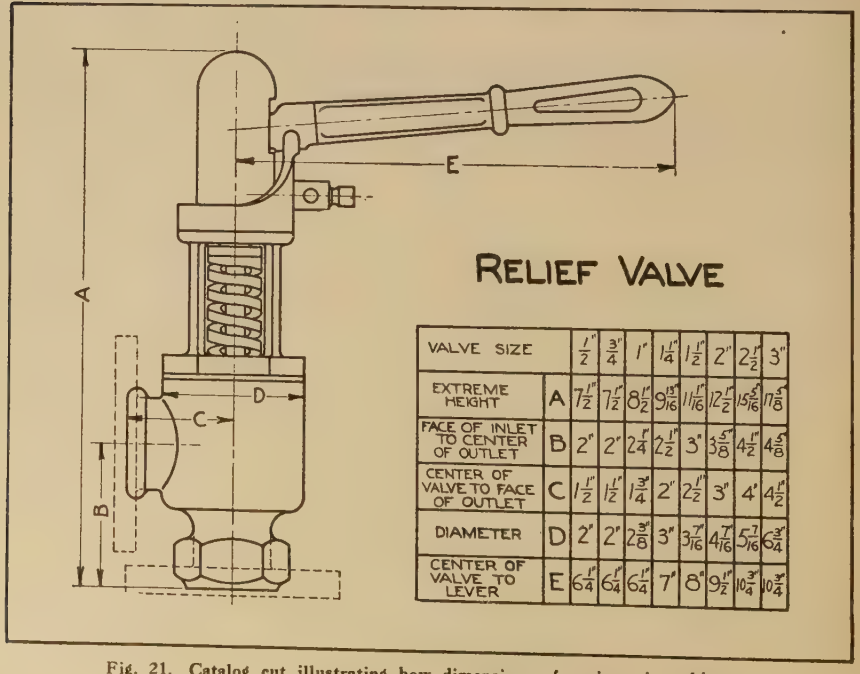
Plate 23A



SIZE	NO.	O.D.	I.D.	T.
2 1/2	40	3 1/4	2 1/2	3/16
3	52	3 3/4	3	1/4
3 1/2	56	4 1/2	3 1/2	1/4
4	60	5 1/8	4	1/4
4 1/2	65	5 13/16	4 1/2	1/4

HOSE GASKET

Supplementary Plate 23



VALVE SIZE		1/2"	3/4"	1"	1 1/4"	1 1/2"	2"	2 1/2"	3"
EXTREME HEIGHT	A	7 1/2"	7 1/2"	8 1/2"	9 13/16"	11 1/16"	12 1/2"	15 5/16"	17 5/8"
FACE OF INLET TO CENTER OF OUTLET	B	2"	2"	2 1/4"	2 1/2"	3"	3 5/8"	4 1/2"	4 5/8"
CENTER OF VALVE TO FACE OF OUTLET	C	1 1/2"	1 1/2"	1 3/4"	2"	2 1/2"	3"	4"	4 1/2"
DIAMETER	D	2"	2"	2 3/8"	3"	3 7/16"	4 7/16"	5 7/16"	6 3/4"
CENTER OF VALVE TO LEVER	E	6 1/4"	6 1/4"	6 1/4"	7"	8"	9 1/2"	10 3/4"	10 3/4"

Fig. 21. Catalog cut illustrating how dimensions of various-size objects may be given in a schedule

Lesson 24

I. *Purpose*

1. To gain some knowledge of inking, tracing, and blue printing.
2. To apply this knowledge in inking, and tracing two or more mechanical drawings.

II. *General Information: Inking, Tracing, and Blue Printing*

It is usually desirable and often necessary to have a number of copies of a mechanical drawing. For example, a copy should be kept in the drafting room as a record; another is sent to the foreman in each department in which some part of the work on the article is to be done; others are often used by salesmen in selling the product, and so on.

To reproduce a drawing, the process known as "blue printing" is used. The first and most important step in producing a blue print is the making of a good pencil drawing similar to those which the student has made up to this time. The second step is the making of the tracing, which is accomplished by placing a sheet of transparent paper or tracing cloth over the pencil drawing, and tracing the lines in ink. The third step is the printing, which is done by laying the tracing over a piece of blue-print paper and exposing it, from one to four minutes, to strong light which shines through the tracing and produces a chemical effect on the blue-print paper. The print is then washed and dried. The result is a finished blue print.

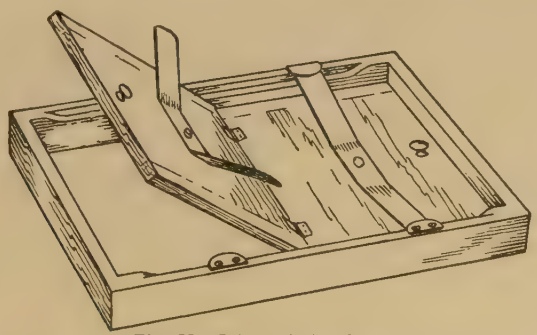


Fig. 22. Solar printing frame

Blue-print paper has a special coating of chemicals, soluble in water. Strong light causes this coating to become insoluble in water and turns its color to a deep blue. When a tracing is held firmly against the sensitized surface of the paper and between it and the light, the light shines through all parts of the tracing except those protected by the ink lines. The print is then washed in a bath of water to which a small

amount of potassium bichromate is sometimes added. This removes the coating that was under the lines of the tracing and results in a print with white lines on a blue background.

Where only a few prints of small size are to be made, a sun frame, like the one shown in Figure 22, is satisfactory. The sun is not a very dependable source of light for this purpose, however, because direct sunlight is desirable, and printing cannot be done satisfactorily on cloudy days.

Most blue prints are now made in special machines in which artificial light is used. See Figure 23.

Drawings are always made in pencil in the beginning. Frequently the pencil drawing is made directly on tracing paper, and the print is made

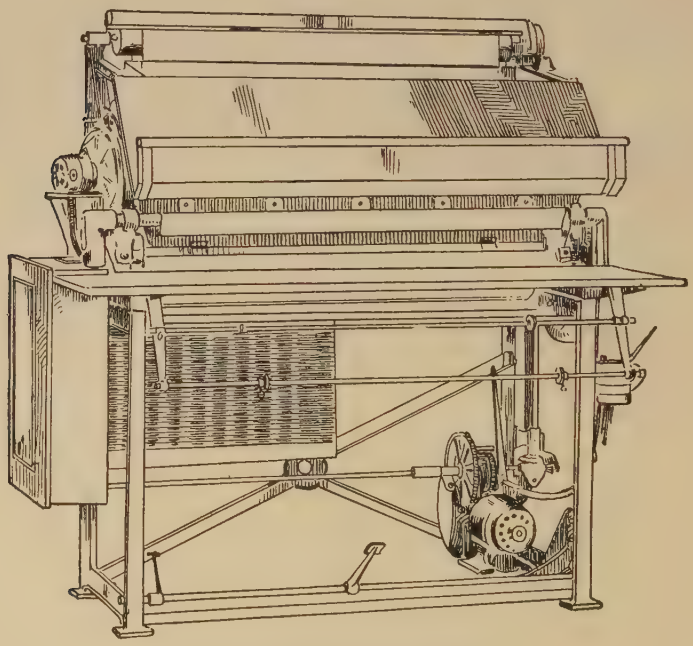


Fig. 23. Blue-printing machine

without inking. This makes rather dim prints, but is satisfactory when the additional cost of tracing or inking is not justified. Sometimes, as in the case of drawings to be put on display, patent-office drawings, or those to be photographed for making printer's cuts, the inking is done directly over the pencil lines on the original drawing paper.

Inking is done with a ruling pen, like the one shown in Figure 24. The width of line is regulated by turning the adjusting screw. To fill the pen, touch the quill from a bottle of standard drawing ink between the nibs, being careful not to get any ink on the outside of the blades. To avoid blotting, do not fill to a height of more than 3/16″ to ¼″. Hold the pen upright, and incline it slightly in the direction in which the line is being drawn. Ink in circles and arcs before inking straight lines.

Fig. 24. Ruling pen

Sources for further study:

French: *Engineering Drawing*, pp. 28 to 32, and Chap. XV.

III. *The Problem*

To ink the plate drawn in Lesson 5. Trace Plate 14, using either tracing paper or cloth. The instructor will probably demonstrate the method of making a print from one of the tracings.

IV. *Suggestions for Procedure*

Observe the general instructions given above, and take note of the following cautions:

1. Fasten the tracing paper smoothly over the drawing.
2. Do not attempt to use the ruling pen free-hand.
3. Do not press the pen too hard against the T square.
4. Do not permit the T square or triangle to touch a freshly inked line.
5. Never use a blotter on inked lines.
6. Never screw the nibs of the pen too tight.
7. Never leave the ink bottle uncorked.
8. Never hold the pen over the drawing while filling.
9. Never allow the pen to run dry in the course of drawing a line.
10. Never put the pen away without cleaning it thoroughly.
11. Be careful to stop ink lines exactly at points of tangency.

Lesson 25

I. *Purpose*

1. To become familiar with the type of drawing used in connection with boat manufacture.
2. To gain some experience in making a boat drawing.

II. *General Information: Boat and Marine Drawing*

In the design and manufacture of canoes, rowboats, launches, tugs, river and lake freighters, submarines, battleships, ocean liners, and other types of boats and ships, mechanical drawing has many important uses.

Marine drafting is really a combination of machine and architectural drawing, plus a certain amount of special work. The working drawings of a large ocean liner involve all the different kinds of knowledge and drafting skill required to design all the details of a great city hotel, and in addition, the designer must be familiar with the special requirements of sea-going vessels. Men whose business it is to design ships are called "marine architects."

Most of the boat drawing done outside of the great ship-building centers is concerned with small boats. Plate 25A illustrates how the hulls of such boats are represented. Usually the drawing is divided on the center line. On one side of the line, the curves show the cross-sectional shape of the hull at several points as seen from the bow or front. The other half of the view shows the shape as seen from the stern or rear of the boat. The points at which these sectional outlines are taken are marked on the top view or plan by reference lines labeled with letters A, B, and so on.

A top view called a "plan," and a broadside view referred to as an "elevation," also are usually drawn. The plan generally includes a number of lines which show the shape of the hull as it would appear if cut horizontally at various points. (These lines, as well as the side view, are omitted in Plate 25.) The locations of these cutting planes are shown by horizontal lines on the elevation.

Detail drawings of all the mechanical and architectural features of boats are very similar to the same types of drafting in other connections. The general principles of orthographic drawing and dimensioning apply here.

III. *The Problem*

Study the accompanying plates, especially Plate 25A. Copy one of the plates, or make another drawing similar to one of them.

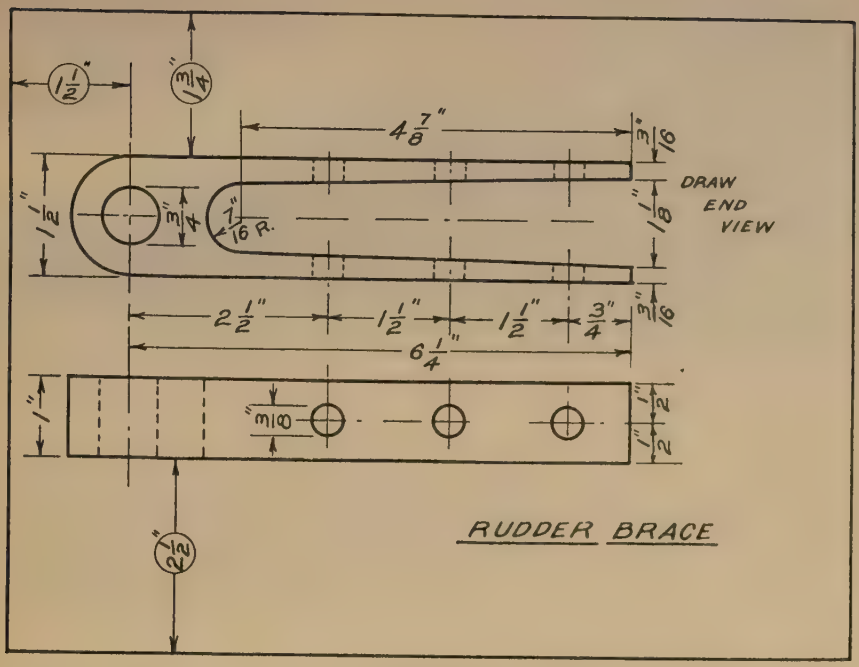


Plate 25C

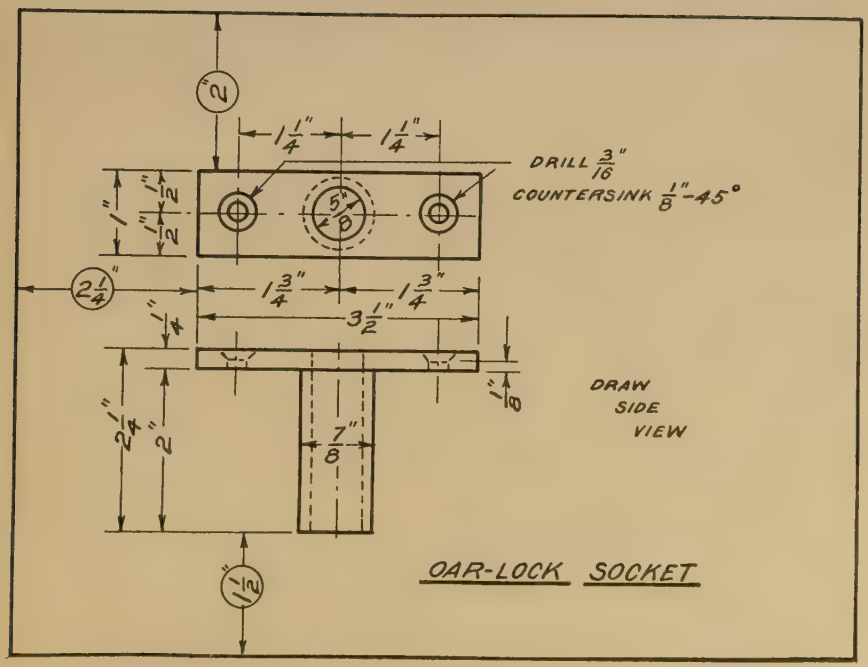


Plate 25B

Fig. 26. A modern airplane. (Courtesy Curtiss Flying Service)

IV. *Suggstions for Procedure*

1. Plates 25C and 25B are similar to other machine drawings, and need no further suggestions.

2. In Plate 25A, the contour lines may be drawn free-hand. As an additional problem it is suggested that the side view of the boat be drawn. Note that a different scale is used in the two views shown.

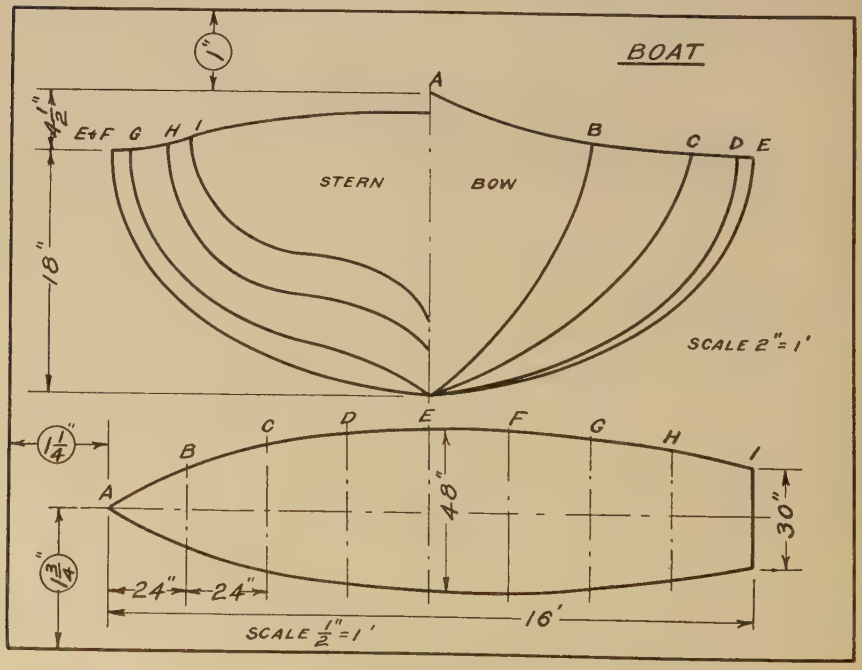


Plate 25A

Lesson 26

I. *Purpose*

1. To gain an appreciation of the increasing importance of the airplane industry and the relationship of drawing to it.
2. To make a detail drawing of some part of an airplane.

II. *General Information: Airplanes and Airplane Drawing*

The first successful flight of a heavier-than-air machine was made by the Wright brothers in 1903. However, the basic principles of flight had been known long before that time. The ordinary kite and the Australian boomerang, to say nothing of living birds, have made applications of these laws for centuries. As everyone knows, however, aviation is only now becoming commercially practical, and the future possibilities in this field can only be guessed.

We read a great deal in the newspapers and elsewhere about the pilots who have made record-breaking flights, and, although great credit is due them for their courage and flying skill, they are not the only heroes of aviation. The men who have toiled patiently for years to perfect the design of wings, fuselages, propellers, motors, etc., should also receive from the public the credit due them. Col. Charles Lindbergh could never have made his epoch-making flight across the Atlantic had it not been for the skill and knowledge of technical men which made the construction of his plane possible. He, himself, recognized this fact in his book which he named "We." The name of Lawrence, the engineer who designed the Wright Whirlwind motor, should perhaps stand side by side with that of Lindbergh in connection with the transatlantic flight.

One fact that the student should not overlook is that the recent tremendous development of aviation is opening up a new field for technically trained men, including draftsmen. These men need not be aviators, but a great deal of special knowledge is necessary, and some actual flying experience is found to be of value. The aviation draftsman's knowledge is like that of the machine draftsman insofar as it concerns motors, undercarriages, and the like. Otherwise it is a wholly special type of work.

For the student who is seriously interested in this branch of work, several of our larger engineering colleges are now offering special courses. For the present, however, the boy who cannot go to college may get a start if he will learn all he can about machine drawing in high school or trade school, and study aviation on the side. The study and construc-

tion of model planes is a good way to begin. At the age of 18 or 20, it should be possible to get a rather poorly paid beginner's job with some firm engaged in the design and manufacture of airplanes.

The drawings in Plates 26C, B, and A illustrate some of the more simple parts of a plane. Note the shape of the wing section in Plate 26A. The thick front edge, flat bottom, and rounded top, serve to create a partial vacuum just above the rear edge of the wing as it is driven at high speed through the air. This tends to lift the plane, because of greater air pressure under the wings than above them.

Sources for further study:

Garber: *Building and Flying Model Aircraft.*

III. *The Problem*

To make a working drawing of some part of an airplane.

IV. *Suggestions for Procedure*

In Plate 26A the parts marked A and B are end views of spars, built up of mahogany and spruce, to which the wing ribs are fastened. The outline of the front view should be drawn by connecting the points shown, with a French curve or a free-hand line.

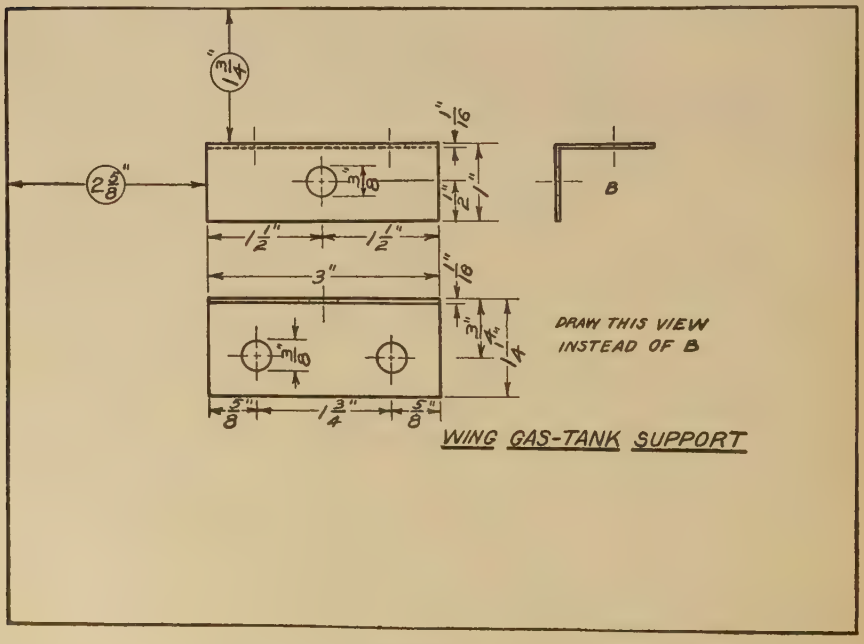


Plate 26C

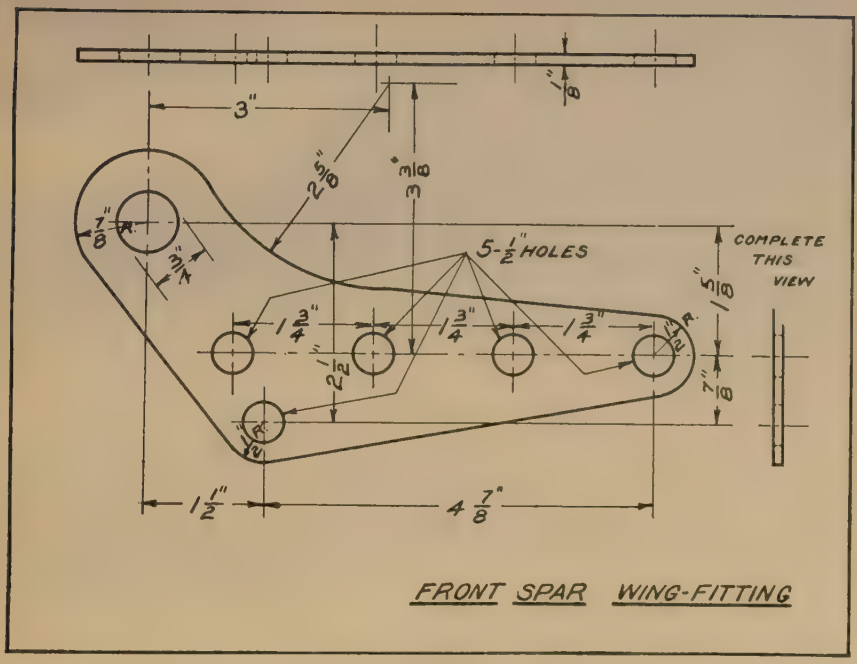


Plate 26B

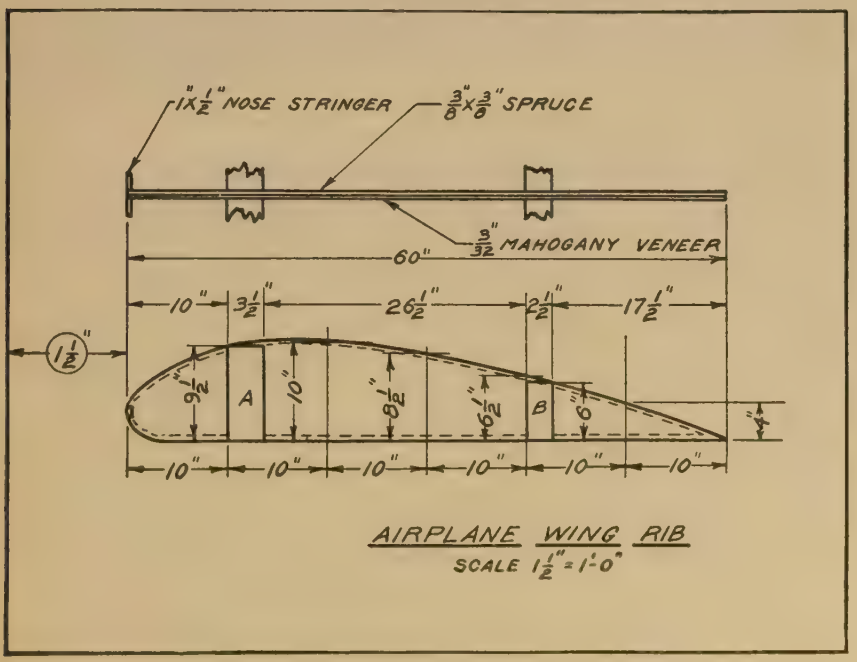


Plate 26A

Lesson 27

I. *Purpose*

1. To acquire some knowledge of patents and the drawings used to represent them.
2. To make a drawing according to patent-office requirements.

II. *General Information: Patents and Patent-Office Drawing*

In order to encourage invention and insure inventors a just return for worth-while accomplishments, the national governments of practically all countries grant letters patent to inventors. In the United States, a patent is a legal document issued by the Federal Government, granting an inventor the sole right to make, use, or sell his invention for a specified period of time. In effect, such a patent is a contract between the government, representing the public, and the inventor who agrees to disclose his invention to the public and in return receives from the government the right to exclude others from making, using, or selling it for a period of 17 years, and places the Federal Courts at his disposal to aid him in punishing any invasion of this right.

A patent may be secured on any *new* and *useful* invention or discovery relating to:

1. An art, including a new and useful process.
2. A machine.
3. A manufacture, such as a new tool, hinge, article of wearing apparel, or any other new and useful article or device.
4. A composition of matter, such as paint, dye, ink, paper, metal, etc.
5. Any new and useful improvement in any one of the four preceding groups.

The process of obtaining a patent is a very technical one, and anyone wishing to secure a patent should place his case in the hands of a reliable patent attorney.

A complete application for patent involves the following:

1. A *petition,* with power of attorney, signed by the inventor.
2. A *specification,* signed by the inventor, which sets forth a full description of and all the claims made for, the invention. It is in this connection that a competent patent attorney is most needed.
3. An *oath,* signed by the inventor before a proper official.
4. A drawing made according to the Patent-Office Rules of Practice. (Formerly, working models were required but the practice has been discontinued.)
5. The filing fee of $20.

Feb. 23, 1926. 1,574,176

J. R. SIEGER

WRENCH

Filed Dec. 18, 1924

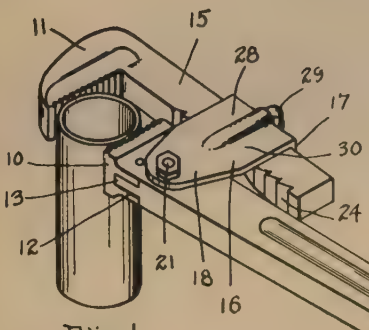


Fig. 1

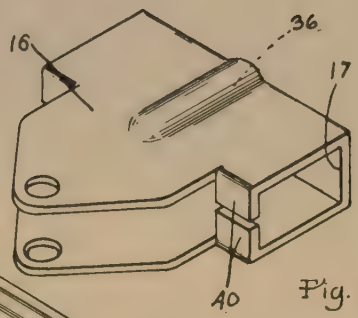


Fig. 5

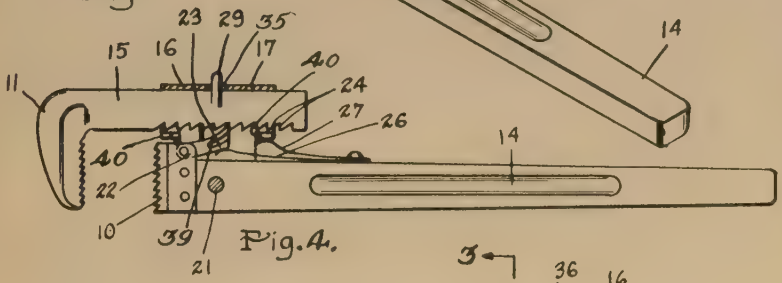


Fig. 4.

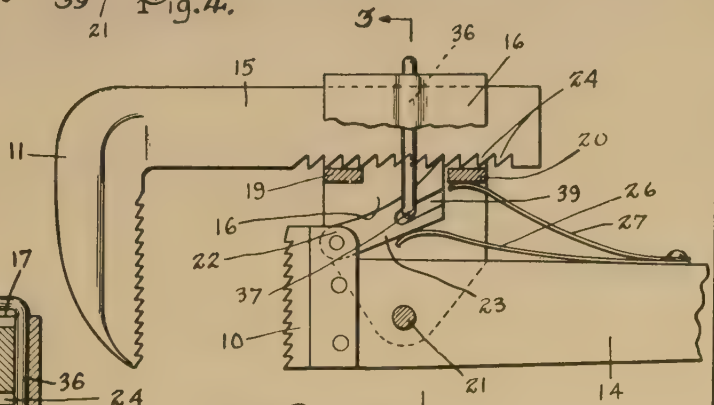


Fig. 2

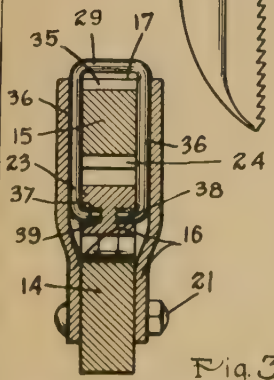


Fig. 3

INVENTOR

John R. Sieger

BY

Alex. Sagaard

ATTORNEY

Plate 27

The total cost of securing a patent varies greatly, but for ordinary cases it will probably not be less than $100, including attorney's charges, government fees, and cost of making the drawings.

Patented articles are required to be marked with the date on which the patent was issued. Often the words "Patent Pending" or "Patent Applied for" are seen on manufactured articles. This marking is not required, but in case an inventor wishes to begin making and selling his invention, during the period between making application and the time when the patent is granted, he uses this means to warn others from copying until it is known definitely whether or not a patent will be issued.

The drawings are a very important part of the application. A very high standard of draftsmanship is required in them, and they must conform exactly to the rules of the Patent Office. These are set forth in great detail in a free pamphlet called *Rules of Practice* which may be obtained by addressing the Commissioner of Patents, Washington, D. C. The drawings must be made in India ink on white bristol board exactly 10″ x 15″ in size, with a 1″ margin all around. As many sheets as necessary may be used. Each sheet must be signed by the inventor, his attorney, and two witnesses. A space must be left at the top for the printed title added by the Office.

Patent-office drawings are not working drawings; hence, dimensions, center lines, notes, etc., are omitted. Pictorial drawing is often used. Line shading is used to give the effect of solidity. Plate 27 is a reproduction of a simple patent-office drawing.

Sources for further study:

Richards and Geier: *Patent Law and Practice.* 277 Broadway, N. Y.
Rules of Practice, U. S. Patent Office, Washington, D. C.
French: *Engineering Drawing,* pp. 294–297.

III. *The Problem*

To study a patent-office drawing and make one of the drawings in Lesson 13 or 14 in this style. Use pencil only in this case to save time.

IV. *Suggestions for Procedure*

1. Use cabinet or isometric drawing.
2. Avoid too much line shading.

Suggestive Test 3

Directions: Place a + in front of each statement if it is true, and an O if it is false.

—— 1. A 4-inch bolt is 4 inches long, including the thickness of the head.
—— 2. Two gears directly engaged will revolve in the same direction.
—— 3. In ordinary drawings, the teeth of gears are seldom drawn in detail.
—— 4. The use of notes in a drawing is seldom advisable.
—— 5. Cast iron is more brittle than wrought iron.
—— 6. Abbreviations are never used in drawings.
—— 7. A ruling pen should not be used free-hand.
—— 8. Tracings are always made on tracing cloth.
—— 9. Many blue prints may be made from one tracing.
—— 10. A patent-office drawing is not a working drawing.
—— 11. The U.S.S. thread is the same as the S.A.E. thread.
—— 12. Regardless of the size of the gear wheels, the size of teeth on two meshing gears are the same size and shape.
—— 13. An eccentric is a special kind of cam.
—— 14. A knowledge of machine-shop practice is of great value to a machine draftsman.
—— 15. Blue prints are more expensive than the original drawings.
—— 16. Blue prints cannot be made by artificial light.
—— 17. No drawing will be accepted by the U. S. Patent Office unless it conforms to the *Rules of Practice.*
—— 18. It is good practice for the draftsman to leave such minor details as finish, kind of materials, and degree of accuracy, to the judgment of the worker.
—— 19. The good appearance of a drawing depends a great deal upon carefully made figures and arrowheads.
—— 20. A draftsman may save more time by carefully planning his drawing than by rushing.

As a test of the students' abilities in reading drawings, it is suggested that the instructor supply some exercises such as those to be found in *Blue Print Reading,* by W. W. Sturtevant, or *Blue Print Reading,* by D. W. Castle.

SURFACE DEVELOPMENT AND SHEET-METAL DRAWING

Lesson 28

I. *Purpose*

1. To become familiar with the methods of developing surfaces as practiced in pattern drafting.

2. To gain some experience with these methods in drawing the surface development of a straight-line object.

II. *General Information: Surface Development in Pattern Drafting*

With this lesson we begin the study of a different type of mechanical drawing from that of the preceding lessons. This kind of drawing is called "surface development." It is used in the manufacture of paper boxes and cartons, in the development of patterns for men's and women's clothing, and in the laying out of sheet-metal work, such as pipes, elbows, boxes, furnace jackets, roof gutters, etc. The process merely involves laying out on a flat sheet all the surfaces of an object, straight or curved, so that they may be folded, bent, or assembled in such a way as to result in a hollow object of a desired size and shape. An ice-cream carton, a shoe box, a man's coat, a lamp shade, a funnel, a baseball cover, and a gasoline tank, are all examples of such objects.

The making of such layouts or "surface patterns," as they are called, is not difficult to understand. They are often considered difficult because of

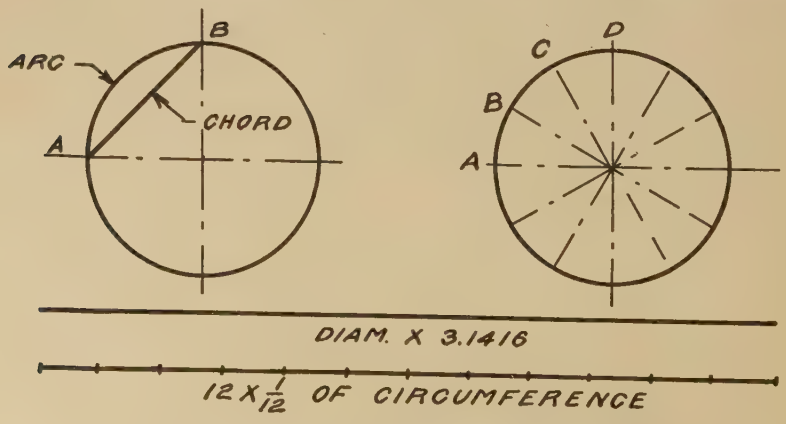


Fig. 28. The difference between arc A–B and chord A–B is considerable, but the difference between the sum of chords A–B, B–C, and C–D closely approximates the arc A–D

the many lines involved. The unfamiliar shapes of the patterns, also, make the drawings confusing. In objects such as boxes, square pipes, and the like, in which all the surfaces are flat, the surface development is merely a connected drawing of all the true views of the object. In a true view all the lines are true length.

The development of curved surfaces, or flat and curved combined, involves some special problems. The surface of a cylindrical object, such as a furnace pipe, is the most simple of these. The pattern here is merely a rectangular piece of metal, the length of which is equal to the length of the pipe and the width of which is equal to the circumference of the pipe plus what metal is needed for making the seam or joint. The circumference may be found by multiplying the diameter by 3.1416 or about 3 1/7. However, the sheet-metal-pattern draftsman usually finds this length, as well as that of all other curved lines, by dividing it into a large number of short lengths so that each short, curved length is about equal to the straight line connecting the same points. (See Fig. 28.) This method is sufficiently accurate for all practical purposes, and is useful on any type of curved line. The distances are transferred from the curved line to the straight line with a pair of dividers.

To lay out surfaces which are cone shaped, like a funnel or a lamp shade, the curved surface is divided into a large number of very small triangles, which are then laid out side by side on a flat sheet, later to be formed into the desired shape. (See Fig. 29.) This process is much used

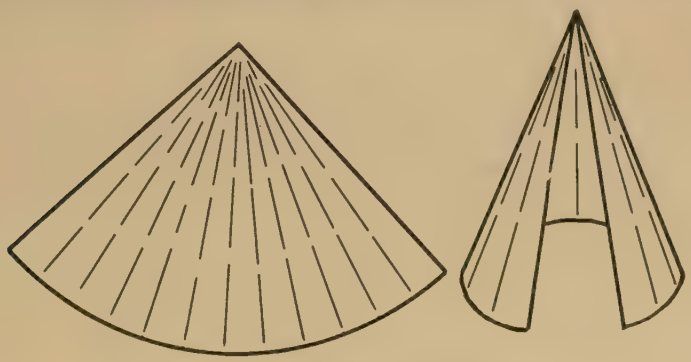


Fig. 29. Laying out cone-shaped surfaces

in sheet-metal-pattern drafting, and is known as "radial development." Another similar method used in developing irregular surfaces is known as "triangulation."

Sources for further study:

French: *Engineering Drawing,* Chap. VIII.

III. *The Problem*

To draw the front and top views of one of the objects shown in Plates 28C, B, and A, and complete the development of its surface.

IV. *Suggestions for Procedure*

1. Draw the front and top views as indicated. The measurements for the surface development will be obtained from these views. It is a good plan to label the lines of the drawing with letters to avoid difficulty in identifying the surfaces in the development.

2. To check the development, draw it on a piece of stiff paper; cut it out and fold the surfaces into position. If this is done, flaps about $\frac{3}{8}$" wide should be left on some surfaces so they may be pasted together.

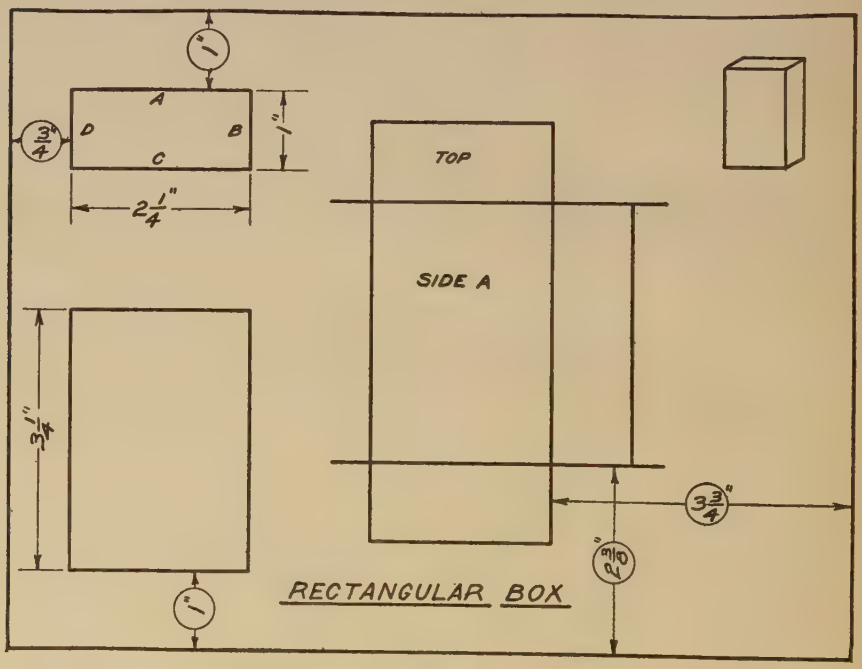


Plate 28C

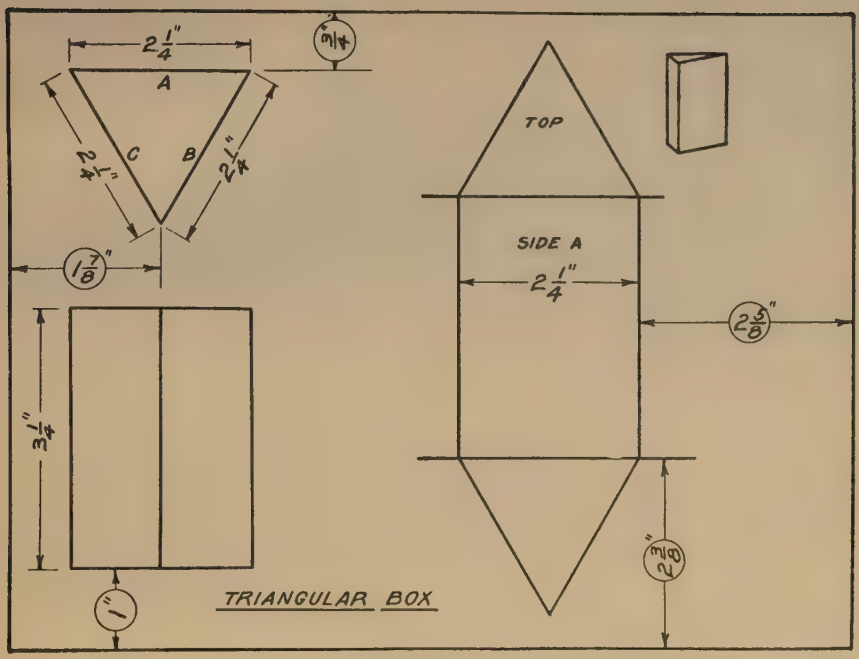


Plate 28B

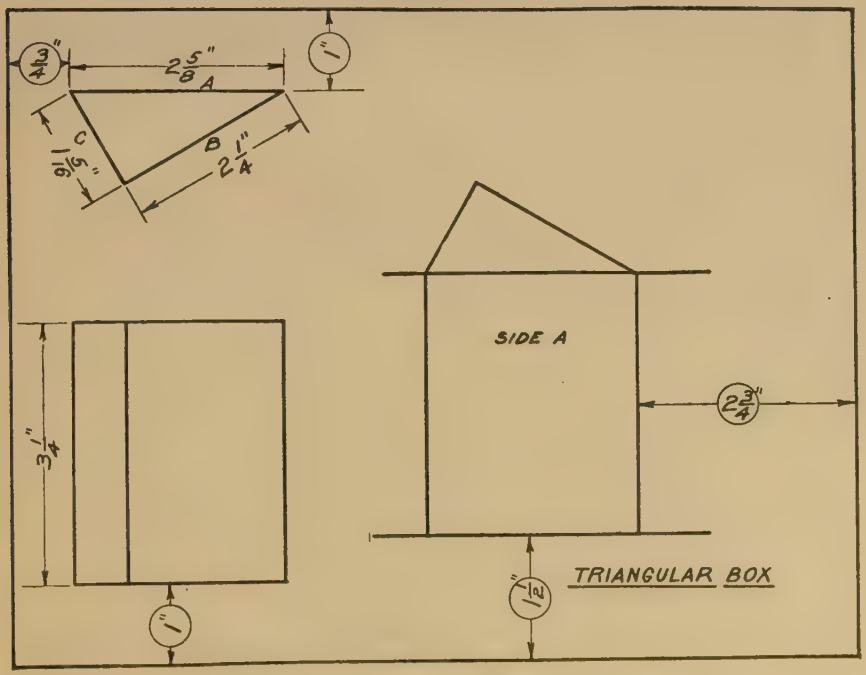


Plate 28A

Lesson 29

I. *Purpose*

1. To gain some appreciation of the products and types of work involved in sheet-metal work.

2. To apply the knowledge gained in Lesson 28 to the development of a cylindrical or conical surface.

II. *General Information: Sheet-Metal Work*

The most important use made of surface developments is in connection with sheet-metal work. Sheet metal is usually sheet steel covered with a thin coating of some rust-resisting material. For example, "tin plate" is sheet steel coated with tin and lead; "galvanized iron" is sheet steel covered with a coating of zinc. Copper, zinc, aluminum, lead, and iron also are used in sheet form.

Sheet metal is provided in various thicknesses. Thickness is indicated by a gauge number. For example, we speak of a 28-gauge sheet which is about 1/64″ thick, or a 16-gauge sheet about 1/16″ in thickness.

The products made from sheet metal may be divided into two general classes; factory products and building-trades work. Factory goods consist of such things as cooking utensils, standard pipe fittings, roof gutters and spouts, automobile fenders, and other specialties, which can be made largely by machinery. Building-trades work is made up of such things as installation of hot-air heating plants, ventilating systems for large buildings such as schools; the placing of metal roofs, gutters, and down-spouts, and all types of work which cannot be completed in the factory and, therefore, require final erection on the job.

The men engaged in such work have been called "tinners." With the growing importance of the use of sheet metal, the old term "tinner" is being discarded, and "sheet-metal worker" is taking its place. Sheet-metal work is now one of the best of the mechanical trades. A young man who wishes to advance in this occupation must study drawing, because the layout work or "pattern drafting," as it is called, is the very foundation of the sheet-metal worker's skill. In the large shops, it is quite common to advance workmen who show unusual skill in pattern drafting to the special work of drafting, in which they develop the patterns used by the less-skilled men in actual construction work.

Sources for further study:

French: *Engineering Drawing,* Chap. VIII.
Welch: *Elements of Sheet Metal Work,* Chap. III.

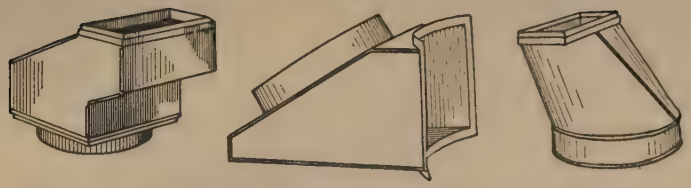


Fig. 29a. Typical sheet-metal developments used in hot-air furnace piping

III. *The Problem*

To draw the top and front views and develop the surface of one of the objects shown in Plates 29C, B, and A.

IV. *Suggestions for Procedure*

1. Same as for Lesson 28.

2. In Plate 29C, the length of the radius "x" in the development is the slant height of the pyramid. It is found in the front view.

3. In Plate 29B, the length of the rectangle which forms the lateral (side) surface of the cylinder is found by stepping off the distance A, B, C, D, etc., on a straight line, until as many steps have been taken as there are spaces in the circumference of the base. In this case there are twelve steps, or spaces.

4. In Plate 29A, the same procedure is followed as in 29B, except that the circumference of the base is stepped off on an arc, the radius of which is equal to the slant height (x) of the cone.

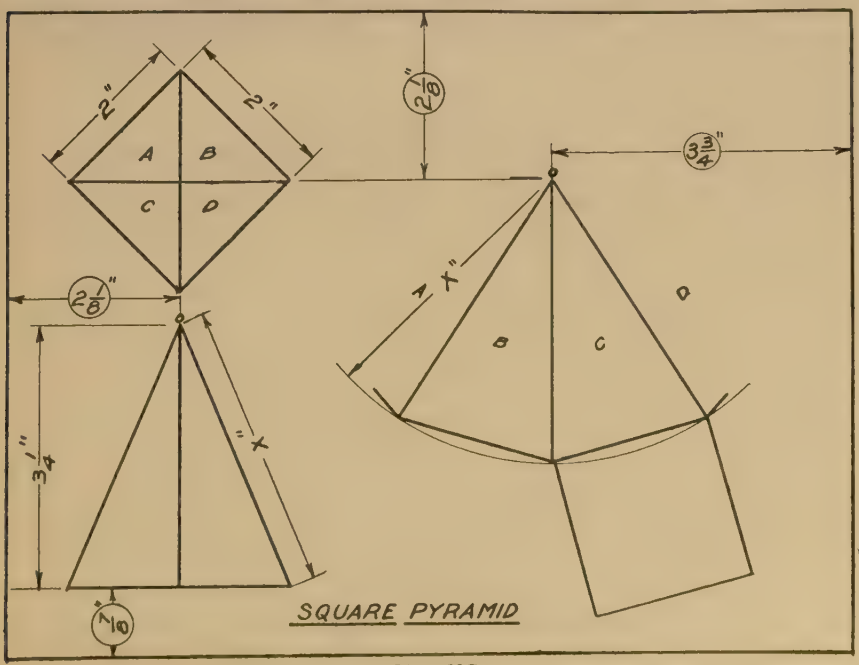


Plate 29C

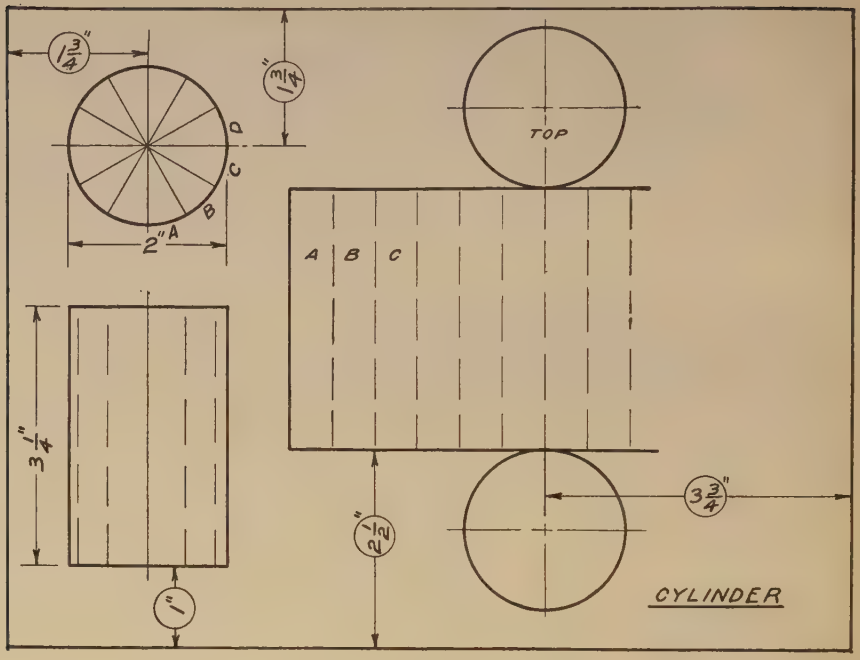


Plate 29B

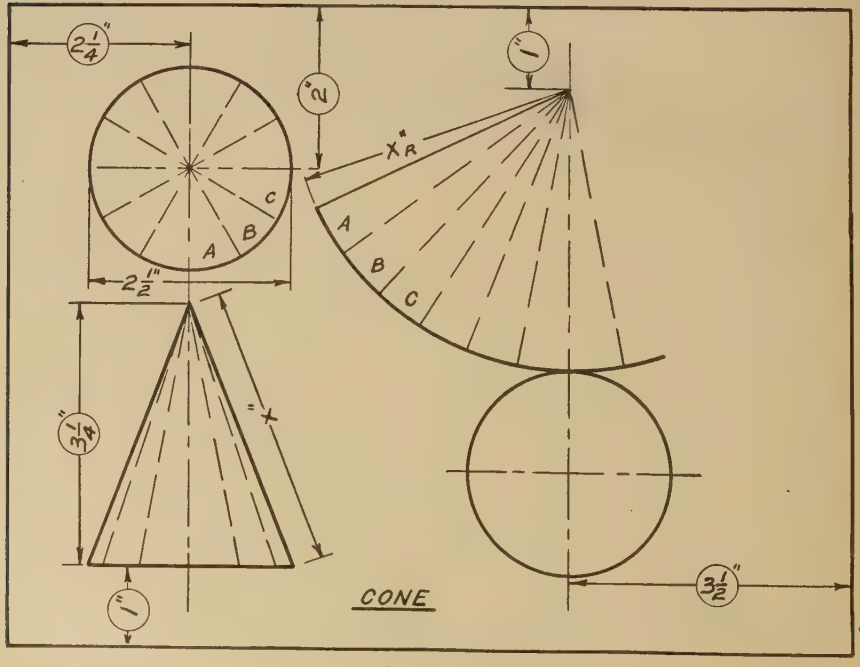


Plate 29A

Lesson 30

I. *Purpose*

1. To acquire some knowledge of shop practice in sheet-metal work.
2. To develop the pattern of a simple object to be made of sheet metal.

II. *General Information: Sheet-Metal-Shop Practice*

The draftsman who is interested in sheet-metal-pattern drafting must become familiar with the common machines and tools used in the shop. Otherwise he may design products in such a way that they will be difficult and expensive, or even impossible to make with the equipment available.

Besides the numerous hand tools, such as riveting and raising hammers, snips, punches, scratch awls, forming stakes, etc., the sheet-metal shop is equipped with a number of machines for performing special operations. For example, a cornice brake is used to make straight, sharp bends; a squaring shear cuts straight edges; a slip-roll forming machine forms sheets into cylindrical shape as in the case of the sides of a tin cup; a bar folder turns edges preparatory to making seams; a wiring machine rolls the edge of a sheet around a piece of wire as in the top of a pail. Besides these, there are crimping, burring, beading, turning, elbow edging, setting-down, and double-seaming machines. There are also circular shears, gutter beaders, and many other special machines. To describe each of these with its special use would require a whole volume. It is enough at this time to know that such machines exist. However, the skilled pattern draftsman must know exactly what each of these devices is capable of doing.

In addition to the tools and machines, the draftsman should know something about the commonly used methods of fastening sheet-metal joints. A number of kinds of folded seams, rivets, solder, and sheet-metal screws and bolts are commonly used.

Sources for further study:

Welch: *Elements of Sheet-Metal Work.*
Broemel: *Sheet Metal Workers' Manual.*
A trip of inspection to a sheet-metal shop.

III. *The Problem*

To develop the pattern for one of the sheet-metal objects shown in Plates 30C, B, and A.

IV. *Suggestions for Procedure*

1. Same as for Lesson 28.

2. In Plate 30C, draw the development only. It is unnecessary to make the pictorial view of the box. The flaps left for fastening the corners may be from 3/16″ to ⅜″ wide.

3. In Plate 30B, draw the development only. Note that two pieces are required. Cut out, fold, and paste to form a pipe joint like the one shown in the pictorial drawing.

4. In Plate 30A, it is unnecessary to draw the top view. The front view with the semicircle below it is required in laying out the development.

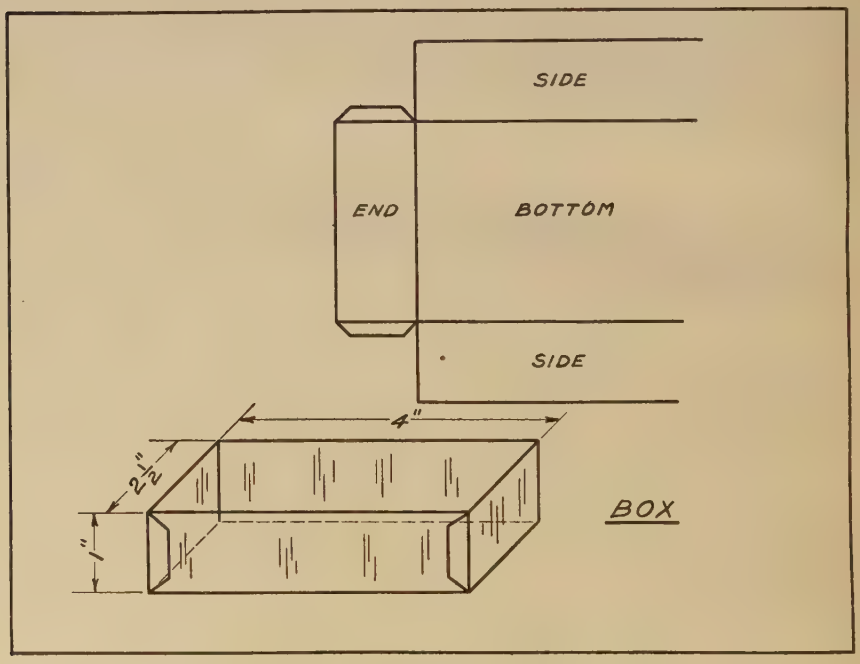


Plate 30C

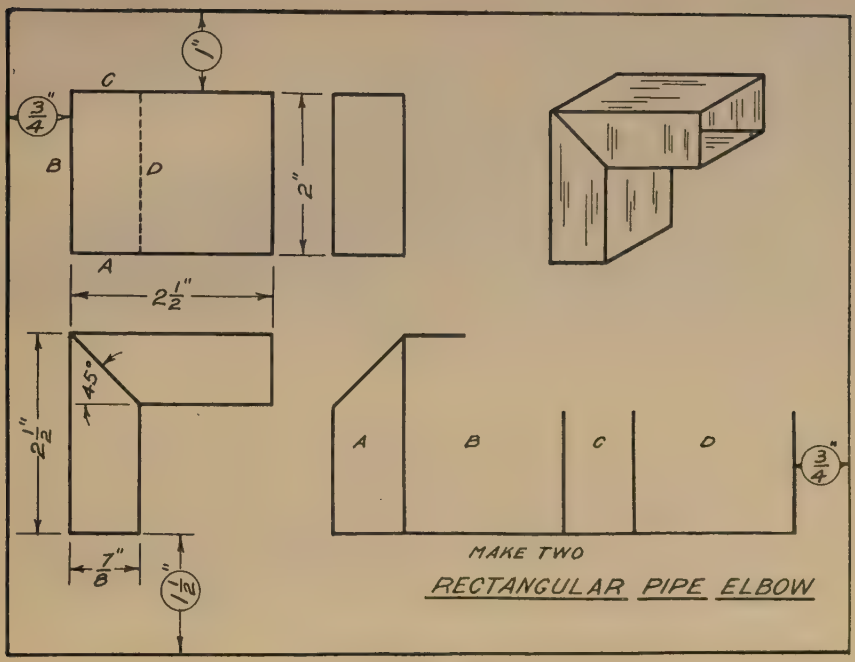


Plate 30B

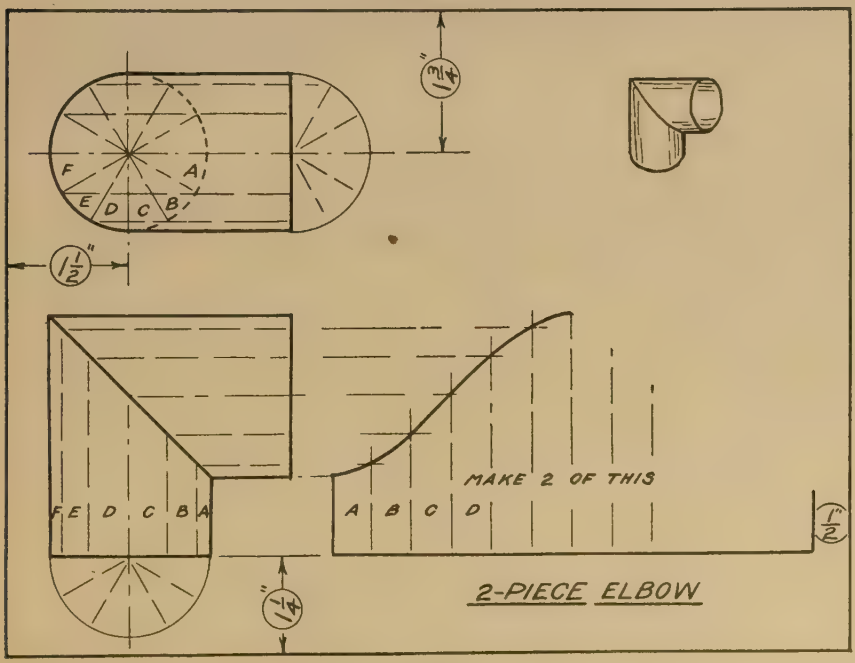


Plate 30A

STRUCTURAL-STEEL DRAWING

Lesson 31

I. *Purpose*

1. To gain some appreciation of structural-steel work and the people engaged in it.
2. To make a drawing involving structural-steel shapes.

II. *General Information: Use of Structural Steel*

This has been called the age of steel and perhaps rightly so, for it is practically impossible to think of a useful thing today, in which steel has not played some part, either as a tool or machine for making, or as an actual part of the product. By structural steel, we mean steel actually used in the construction of large buildings, bridges, cranes, roof trusses, and the like. The use of structural steel has made the American

Fig. 30. A modern office building under construction, showing part of steel frame and stonework. Complete building shown in Figure 41

skyscraper and our huge bridges possible. Figure 30 shows the steel skeleton of a great office building many stories in height, partly covered with brick and stone. However, with brick and stone alone, such a structure would be impractical, if not impossible. At the University of

Minnesota, a huge athletic field house has been erected. It covers nearly an entire city block, yet there are neither partitions nor posts in the entire building. Great semicircular steel trusses span its entire width.

Nearly all of the columns, beams, and braces which make up these structures are made up of a few standard shapes. They are shown in Plate 31B. Each of these shapes comes in many sizes for various purposes, ranging from a ½″ channel used on a boy's coaster wagon, to an I beam several feet in depth, used to span the stage opening in a large theater. These standard shapes, manufactured in steel rolling mills, are cut to length with huge power shears and fastened together with large rivets. Some parts of a structure can always be built up in the factory and later assembled out on the job. Hence, we speak of shop fabrication and field fabrication.

The men who assemble the steel members at the job are known as structural-steel workers. This is a well-paid but dangerous trade. The rat-a-tat-tat heard during the erection of a steel structure is the steel worker's riveting machine operated by compressed air.

The design of steel work involves a great deal of mathematical and engineering ability. No errors are permissible. If one member is too weak the entire structure may fail, causing perhaps a loss of life and certainly expensive damage to property. On the other hand, unnecessarily heavy members entail useless expense. In connection with steel design, we hear such terms as factor of safety, shear, stress, strain, tension, compression, modulus of elasticity, cantilever and continuous beams, moments of force, coefficients of expansion, and dozens of others too technical to be discussed here.

One who hopes to master this type of work should assure himself that he has more than average ability in mathematics, and then take a four-year course of training in a good engineering college. Some schools offer a special course in structural engineering, others make it a part of civil engineering, while still others offer special courses in architectural engineering for those interested particularly in building construction.

Sources for further study:

French: *Engineering Drawing,* Chap. XV.
Cambria Steel Handbook, Cambria Steel Co., Jamestown, Pa.

III. *The Problem*

To reproduce one of the drawings on Plates 31C, B, and A. Study the standard shapes, and learn their names.

IV. *Suggestions for Procedure*

1. In Plate 31C, steel is indicated by the special spacing of the cross-hatching. Other shapes and sizes of rivets are used.

2. In Plate 31B, the dimensions are given as common fractions to make the drawing simpler. In actual practice, the dimensions of standard steel shapes are given in decimals not exactly equal to the fractions used here.

3. In Plate 31A, several ways of combining structural shapes to make columns or beams are illustrated. If it is desired, one of these may be drawn in the center of the plate. The dimensions given in Plate 31B may be used.

Note to teacher: The strength of fabricated steel may be strikingly illustrated by constructing small models of shapes similar to those shown in Plate 31A of heavy drawing paper and paste.

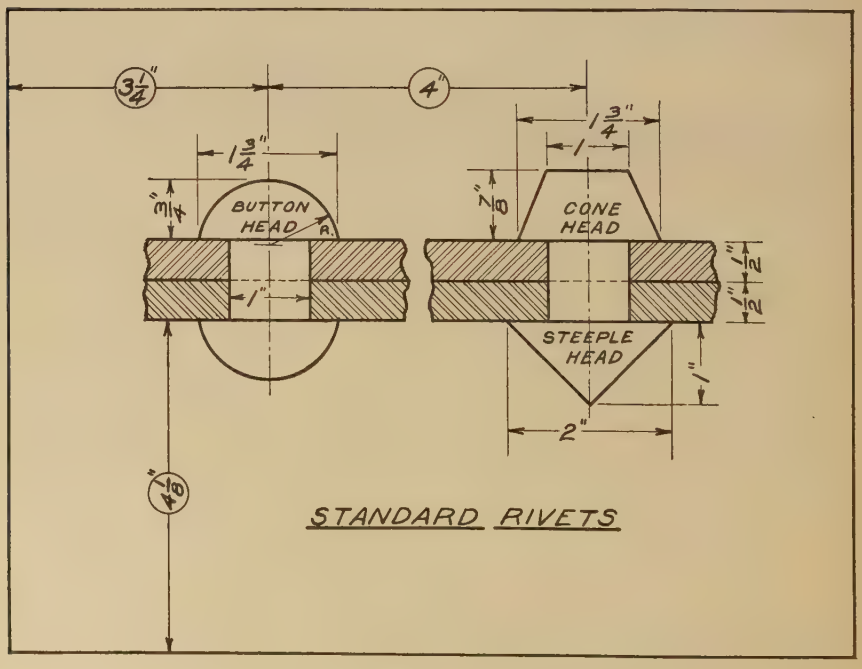


Plate 31C

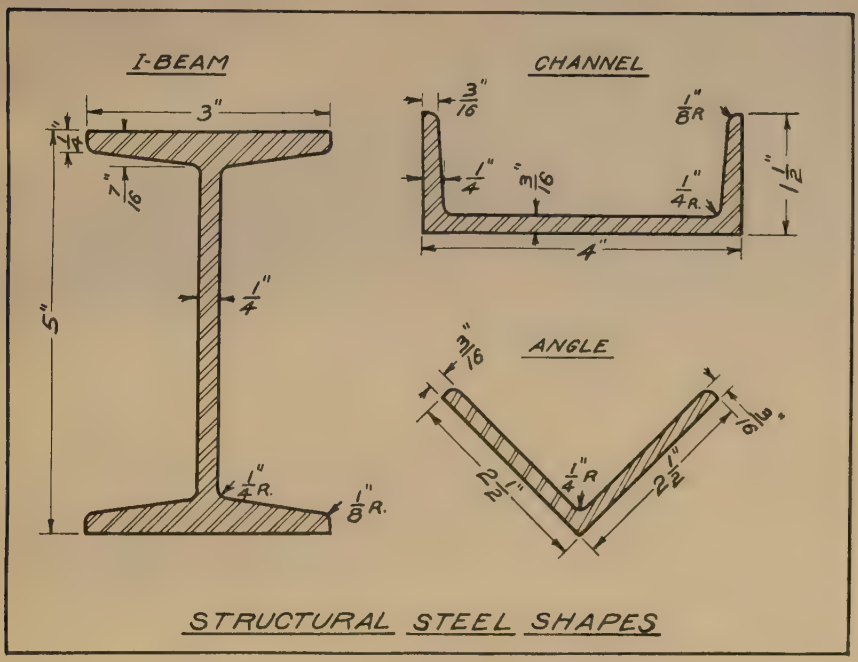


Plate 31B

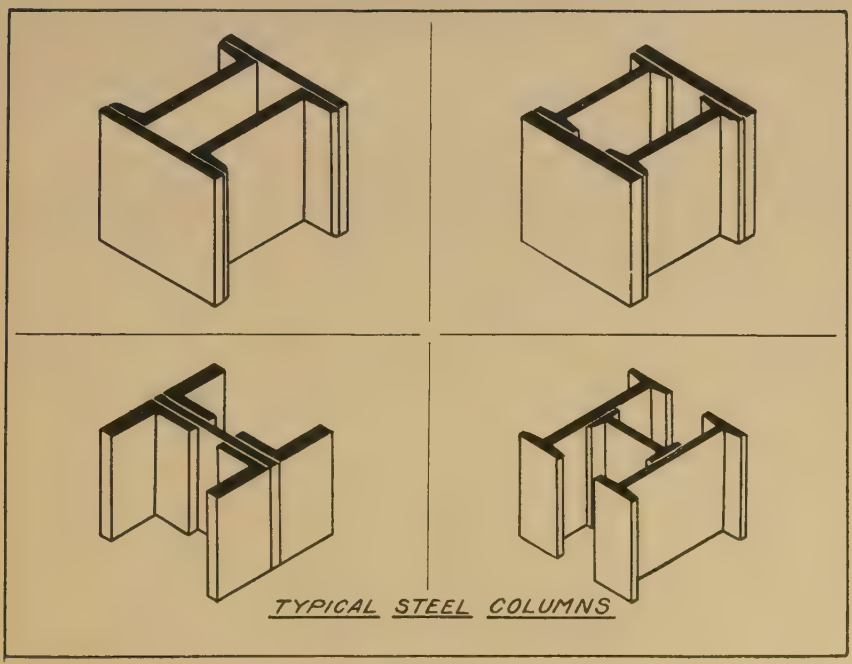


Plate 31A

REINFORCED CONCRETE

Lesson 32

I. *Purpose*

1. To acquire some knowledge of reinforced concrete and its use in industry.
2. To make a working drawing of a piece of reinforced concrete work.

II. *General Information: Nature and Use of Reinforced Concrete*

Concrete is any hardened mass of materials, such as sand, gravel, or crushed rock (called aggregates), held together by a cement. The ancient Romans were familiar with its use, and some of the concrete roads of Caesar's time are still in existence. However, it has been only since the discovery of Portland cement that the great development in the use of concrete has come about. Portland cement is made by subjecting a certain kind of shale (a hardened clay) to very high temperatures. It is then ground to a very fine powder. Certain other materials, such as gypsum, are added. It gets its name from the fact that its color is like that of a stone quarried near Portland, England. When this cement is mixed with aggregates, and enough water is added to thoroughly wet the mixture, the mass will harden in a few hours to a substance which we call concrete. It is really a manufactured rock. Concrete is further strengthened by placing steel rods in the forms and pouring the concrete around them. The purpose of such reinforcing is to increase the bending and tensile strength of the material.

The use of reinforced concrete is rapidly taking the place of structural steel as the skeleton of buildings, and as the chief material in the construction of bridges. In buildings, it has the advantage of being more fire resisting than steel which softens under heat; and in bridges the concrete produces a beautiful effect compared with the ugliness of some steel structures. The uses of concrete in paving, dams, foundations, floors, and in dozens of other connections are familiar to everyone. The great development in the use of concrete is fast making it our most important structural material.

Over a quarter of a billion barrels of cement are manufactured in the United States in a year, and we are building about 7,000 miles (more than one fourth of the earth's circumference) of concrete pavement per year. We now (1930) have about 60,000 miles of paving in the country. Road building has become an important engineering specialty.

At least two new trades also have developed from the use of concrete. The *form builder* is a specialized type of carpenter, and the *cement fin-*

isher's work is similar in some respects to that of the mason and the plasterer.

The draftsman engaged in work involving the use of concrete will find it necessary to learn the methods of placing reinforcing; the methods of building forms; the strength of concrete in beams, columns, slabs, etc.; the proper proportions of cement and aggregates for different purposes; and methods of finishing, as well as many other facts and principles too numerous to mention.

Sources for further study:

Vocational Course in Concrete, a pamphlet published by the Portland Cement Association, Chicago, Ill.

III. *The Problem*

To make a working drawing of a concrete project, such as those shown in Plates 32C, B, and A.

IV. *Suggestions for Procedure*

1. Note the convention used to represent concrete "drawn in section."

2. Note that reinforcing materials are placed near the surface in which cracks are most likely to develop. Never place reinforcing at the center (neutral axis) of a slab or beam.

3. Moldings and curves in concrete design should be large and heavy. Those which are too intricate are almost impossible to carry out.

4. Note that a different style of drawing is used in these plates. This is the architectural draftsman's technique. Lines cross slightly at corners, and dimensions are written on top of the dimension lines. Note other differences, such as lettering, conventional break, etc.

5. In Plate 32C, since the flower pot is square, only one view and a partial section is required. The free-hand hatching in the panel indicates a rough stippled surface.

6. In Plate 32B, the perspective need not be drawn. Why are the reinforcing rods placed below the center of the top slab? It is suggested that, instead of copying this bench, a similar one of a different design be drawn. The end view is not completely dimensioned for this reason.

7. In Plate 32A, the perspective need not be drawn. Change the side elevation to a sectional view as suggested at the upper right. Space in the middle of the paper.

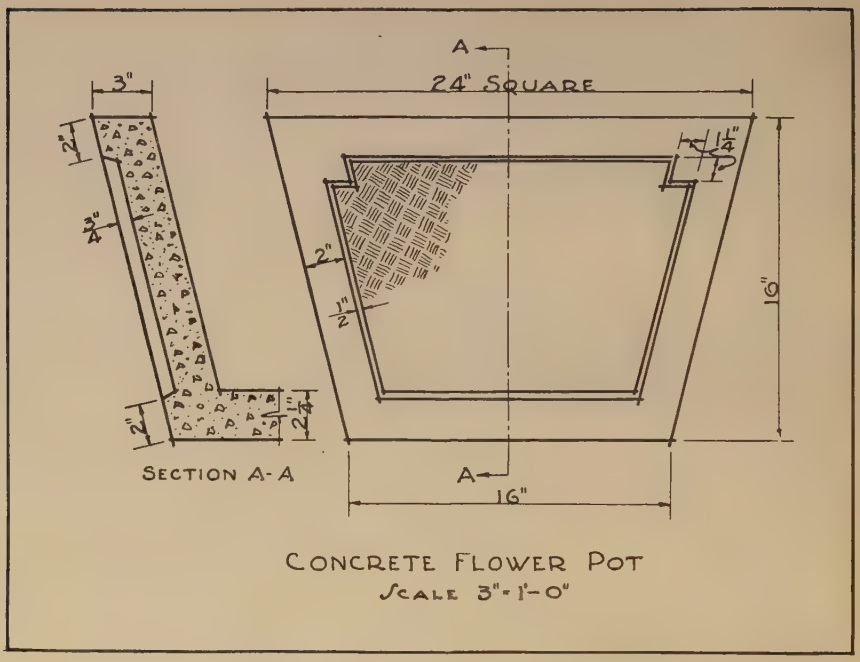


Plate 32C

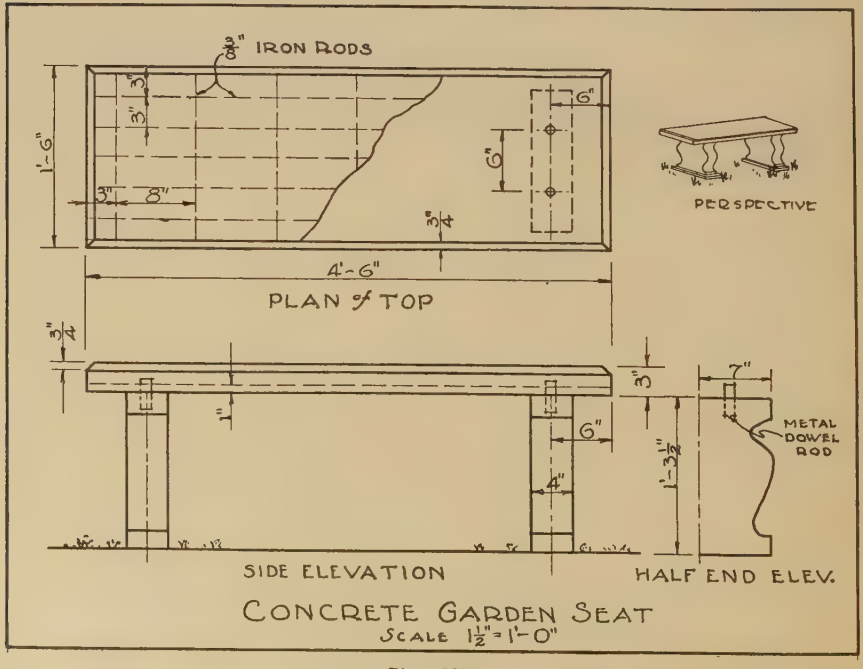


Plate 32B

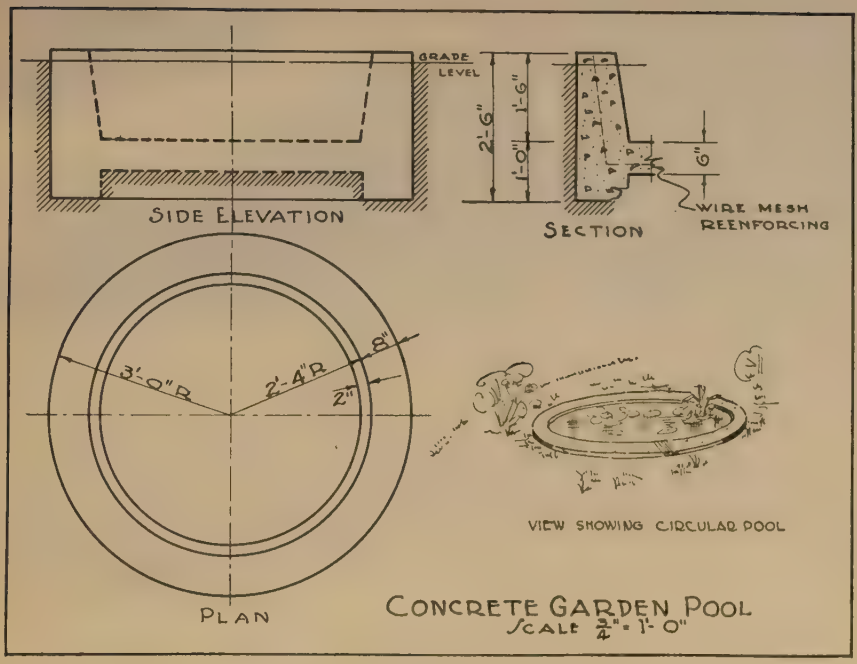

GRADE LEVEL
2'-6"
1'-6"
1'-0"
6"
SIDE ELEVATION
SECTION
WIRE MESH REENFORCING
3'-0" R
2'-4" R
8"
2"
PLAN
VIEW SHOWING CIRCULAR POOL
CONCRETE GARDEN POOL
SCALE 3/4" = 1'-0"

Plate 32A

Suggestive Test 4

Directions: Fill in the blanks to make the statements true.

1. A drawing which shows the complete surface of an object on one flat sheet is called a ————.

2. The complete surface of a cube is made up of ———— squares.

3. The development of a tin cup without a handle consists of ———— rectangles and one ————.

4. A surface layout consisting of four equal triangles and one square is the development of a ————.

5. The tradesman who makes the most use of pattern drafting is the ———— worker.

6. Three common objects made by sheet-metal workers are ————. ————.

7. Two methods of fastening sheet-metal joints are ———— and ————.

8. Three common shapes of structural steel are ———————— ————.

9. Structural-steel members are usually fastened together with ———— ————.

10. A mixture of gravel, sand, Portland cement, and water is called ————.

11. Steel rods placed in concrete to make it stronger are called ———— ————.

12. Besides its use in buildings, the greatest use made of concrete is in the construction of ————.

PRINCIPLES OF DESIGN

Lesson 33

I. *Purpose*

To gain some appreciation of the principles of and the need for design for the sake of beauty.

II. *General Information: Fundamentals of Design*

A design is a scheme or plan upon which some object is constructed, as the design of an airplane motor or that of a house or a piece of furniture. Every design is based on two major considerations, utility and beauty. As we shall see, these two elements are really only one, for the very foundation of design is to so shape an object that it will best serve its purpose from all points of view. If a device, a machine, or a building is useful and wholly suited to its purpose, it will have beauty. On the other hand, it could not be truly beautiful unless it were useful. *Beauty and utility develop hand in hand.* The history of the automobile, the locomotive, the highway bridge, the carpenter's plane (Fig. 32), the hunter's rifle, and in fact almost every manufactured article in existence, is an example of this fact.

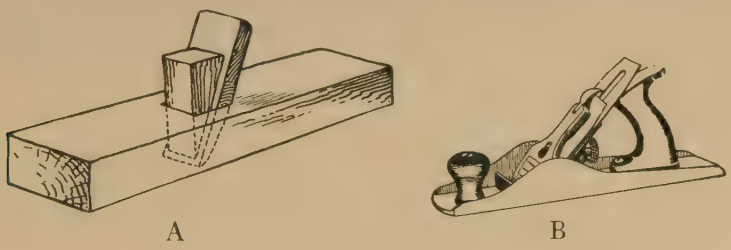


Fig. 32. A is a plane used by the ancient Hebrews. It was made by inserting a sharp stone through a block. B is a modern metal plane. These planes illustrate the fact that beauty of line develops parallel with usefulness

Many people have a limited and false idea of the true meaning and importance of art and design. They associate the words with people of queer manners, garret studios, flowing bow ties, long hair, and the like. They think only of the fine arts of sculpture and painting, and their ideas of these are largely derived from overdrawn storybooks.

By far the greatest amount of art to be found in this world is in the common things of everyday life. A jackknife, a child's toy, a shovel, a hat, or a barn, may express the fundamental principles of good design as well as a painting by Michelangelo.

Any design may be created or judged on a basis of five elements. These are balance, symmetry, rhythm, harmony, and unity. These are well defined in detail in a little book called *Essentials of Design* by DeGarmo and Winslow. To enter into a worth-while discussion of these abstract elements of design, with examples, would require too much space for the present purpose. However, a draftsman in any field of work will find it to his advantage to have some appreciation and a working knowledge of the basic principles of artistic design.

In connection with the foregoing principles, a few practical rules of design may be applied successfully by anyone, and are worth considering here.

Designs should be in scale with the human figure. We design things for the use of human beings. Hence, a table fork has a size and shape most suitable to the human hand and touch. This idea influences all of man's handiwork from a locomotive to a watch, and from a book to a skyscraper.

The use to which an article is to be put is an important consideration in making the design. The use should, therefore, be expressed in the design; that is to say, a factory building should look like a factory, not like a library, nor yet like a barn. A shovel is not nickel plated, but is made of good sturdy steel and wood, and gives the appearance of being able to serve the purpose for which it was intended.

All imitations are false design. In other words, a design should be a frank and honest expression of the materials used. Some common violations of this principle are seen in sheet iron made to look like stone, metal painted to imitate wood, and electric-light fixtures patterned after candelabra. One would think that some of our most useful modern inventions were things of which to be ashamed.

Avoid meaningless ornamentation. All ornamentation, such as carvings, moldings, inlays, and relief work, must have a real and definite purpose in carrying out the design. Too much ornament is a worse fault than too little.

The world has just passed through a century of decadent taste in matters of art. It has been a period in which we either felt no appreciation for the problem at all, or were content to copy the work of earlier ages. We are just now in the full swing of a new interest in art. The appreciation of the beautiful and the appropriate in everyday things will soon be recognized as a part of our daily lives. The business man of today and of the future who fails to give every consideration to the careful design of his products is doomed to failure.

In dozens of occupations the workers are dependent to a very large degree upon their knowledge of the principles of design and how to apply

them to their work. Some of these are architects, landscape architects, interior decorators, window decorators, engravers, artists, jewelry designers, advertising illustrators, magazine illustrators, cartoonists, automobile-body designers, costume designers, and so on through an endless list of designers of commercial specialties.

Sources for further study:

Varnum: *Industrial Arts Design.*
DeGarmo and Winslow: *Essentials of Design.*

III. *The Problem*

Study the preceding paragraphs and see if you can supply one or more examples (not found in the text) of each principle. If possible, read chapters I and II of *Essentials of Design.*

Note: If the instructor has them at hand, it would be interesting and worth while to give a standard test of art ability.

FURNITURE DRAWING

Lesson 34

I. *Purpose*

1. To learn something about the work of a furniture draftsman and modern methods of manufacturing furniture.
2. To make a furniture drawing.

II. *General Information: The Designing and Manufacturing of Furniture*

Few items of equipment are as important in making one's home pleasant and agreeable as the furniture used in it. The designers and draftsmen who plan furniture must have artistic taste and an intimate knowledge of the needs of American homes. In addition, the designer must know the

Fig. 34. Armchair, Charles I. 1625. Jacobean period

Fig. 35. Walnut dressing table, 1690—1700. William-and-Mary period

Fig. 36. Heppelwhite sideboard. 1790–1800. Serpentine front and square tapering legs

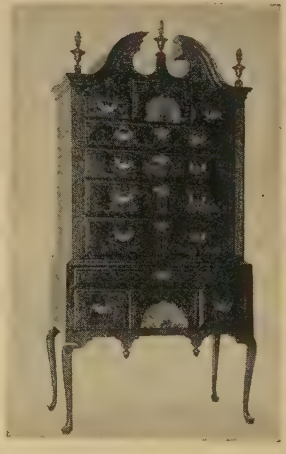


Fig. 37. Queen Anne tallboy, constructed of walnut, with veneered and inlaid drawers

characteristics of the classical period designs, such as the American Colonial, Chippendale, Jacobean, Queen Anne, Heppelwhite, Louis XVI, and many others, so that he may make use of what has already been learned in creating new designs for modern use. Many people, not designers, find the study of period furniture a fascinating pastime.

Besides this artistic kind of information, the designer of furniture must have at his command a great deal of knowledge about woods, finishes, upholstering fabrics, and other materials. The machines used, methods of construction, prices of materials, cost of manufacture, and selling prices, also must be a part of his knowledge.

When a new design of a radio cabinet or dining-room chair is to be made, the first step is to draw several free-hand pictorial sketches of the piece until a satisfactory design is obtained. Then large-scale (usually full-size) drawings are made of every part, showing exact shapes and sizes. A highly skilled cabinetmaker then makes a sample so that the design may be studied in its final form.

When a design is finally decided upon, full-size detail working drawings are made of every part. These are usually pencil drawings. Tracings and blue prints are seldom used. These drawings are then turned over to the factory foreman or superintendent who works out means for making and assembling the parts. Thousands of pieces are often made from one design.

Some furniture manufacturers make use of what is called the "rod method." A rod is a working drawing consisting of at least three sectional views of the assembled piece such as a table, desk, or cabinet. Part of each view is broken out and the dimensions are given in only one direction. Other dimensions are shown on the other views. For example, the front sectional view would give the height of all parts, the top sectional view the width, and the end sectional view the depth.

Plates 34C, B, and A are samples of detail drawings used in furniture factories. Note that the technique of lines and letters is somewhat different from that used by machine draftsmen. This is the style used by architectural draftsmen.

Ordinary furniture detailers receive pay about equal to that of other skilled tradesmen. They usually enter this work after high-school or technical-school training in general drafting, and learn about furniture drafting on the job. The work is agreeable and not as exacting or complicated as machine or architectural drawing. The natural line of promotion leads to the position of designer. This would, however, require some natural artistic talent and further training in design.

The position of designer is usually filled by a person who has worked up through the drafting room, or by graduates of courses in architecture

or interior decoration. An increasing number of women are entering this field.

We occasionally hear people deploring the cheap factory-made furniture which is on the market today and wishing for the return of the "good old times" when furniture was made by skilled hand workmen. They little realize that in those historic times only the nobility and the very wealthy could afford such furniture. The majority of the people had practically no furniture, and what they had was of the crudest homemade variety. The use of machinery and modern factory methods have brought the price of good furniture within reach of even the poorest people. The writer recently saw an elaborately designed, hand-carved dining-room set which was being made to order. It was to cost the purchaser $4,000. A similar set, made in large quantities by factory methods, probably could have been made for less than $150.

A modern furniture factory has a number of divisions in its production department.* The lumber first comes to the stockrooms and the dry kiln where it is artificially seasoned. Then the stock for any piece of work goes to the millroom, where most of the machine work is done. Here the stock is ripped to width, cut to length, surfaced (planed to thickness), jointed (planed straight), and glued and veneered if necessary. Other machines are provided for cutting moldings, making carvings, shaping irregular surfaces, sanding, etc. Each of these machines is operated by a man (sometimes by a woman) who is highly skilled at his machine, but who is *not* an all-around cabinetmaker able to perform all of the operations in the factory.

From the mill the parts go to the assembling room, where they are fitted and fastened together. In the finishing department the staining, filling, varnishing, and rubbing are done. Here again, different men work on different operations. After the finishing, a given piece of furniture goes to the upholstering department (if necessary), and later to the inspection, packing, and shipping departments.

It will be seen that in the making of a piece like a dining-room chair, which under the old method would have been produced entirely by one workman, as many as fifty or a hundred different men and machines may have done some small parts of the work. This is what is known as *mass production*. The same method makes possible the manufacture of cheap automobiles, clothing, canned fruit, etc.

A knowledge of just how his own factory does its work is essential to the success of a furniture draftsman.

*The production department of any factory is that part of the organization whose business it is to do the actual work of making the product. Other departments are sales, finance, etc.

Sources for further study:

Visit a furniture factory.

The Seng Book, The Seng Co., 1450 Dayton St. Chicago.

Current copies of *The Furniture Manufacturer and Artisan.*

III. *The Problem*

To make a working drawing of a small piece of furniture or of some part thereof.

IV. *Suggestions for Procedure*

1. If the student or teacher wishes, drawings of actual pieces of furniture with which the student is familiar may be substituted for those shown in Plates 34C, B, and A.

2. In Plate 34C, copy the details as shown, or make similar drawings showing other methods of fastening tops. Various edge moldings also may be used. The fine free-hand lines indicate the grain of the wood.

3. In Plate 34B, copy the drawing at the left, and complete the one at the right. Dowel rods are round hardwood pins. Several dotted lines have been omitted from the front view of the mortise-and-tenon joint. Locate them.

4. In Plate 34A, a few necessary minor dimensions are omitted. Work these out with the aid of the instructor, and place them on your drawing.

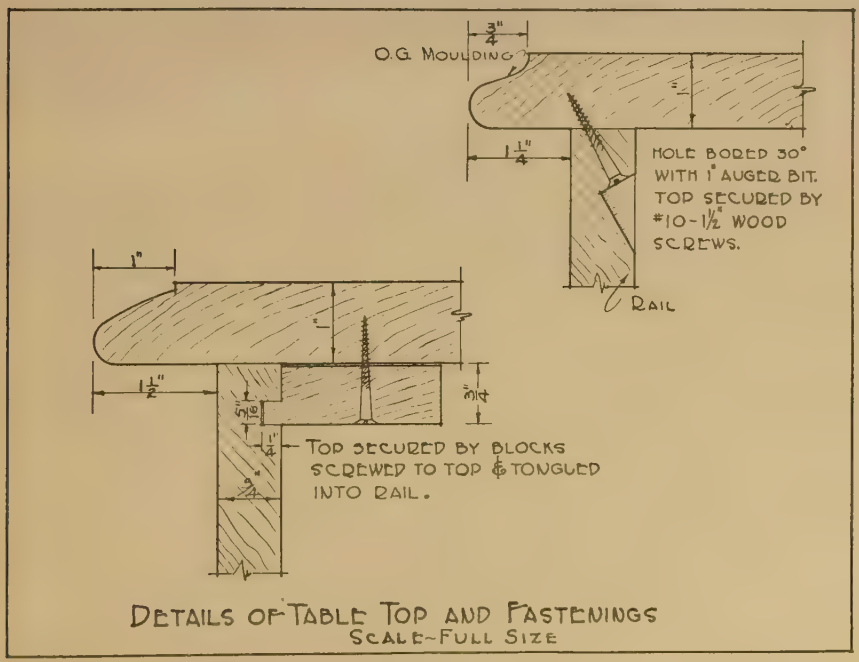

O.G. MOULDING
HOLE BORED 30° WITH 1" AUGER BIT. TOP SECURED BY #10-1½" WOOD SCREWS.
RAIL
TOP SECURED BY BLOCKS SCREWED TO TOP & TONGUED INTO RAIL.
DETAILS OF TABLE TOP AND FASTENINGS
SCALE-FULL SIZE

Plate 34C

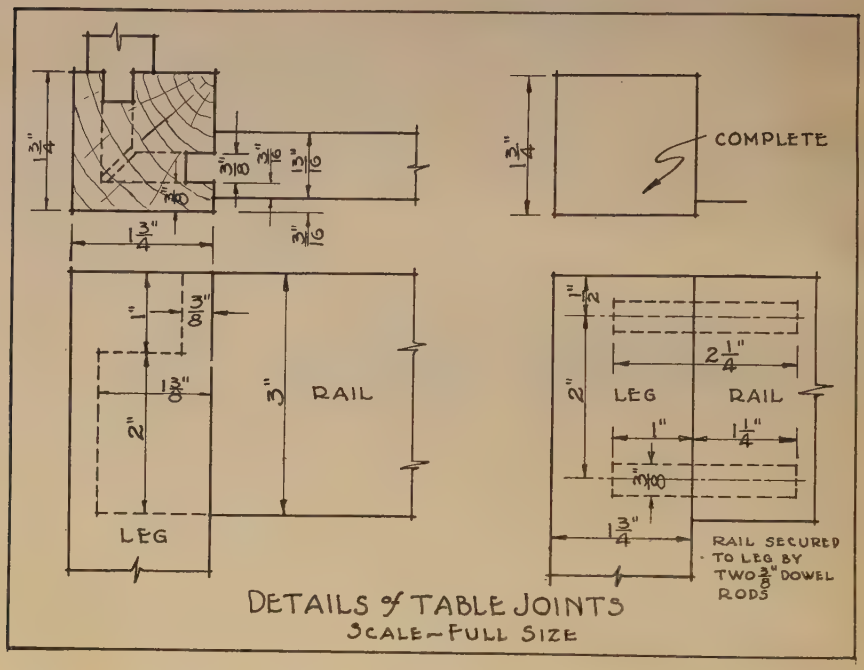


Plate 34B

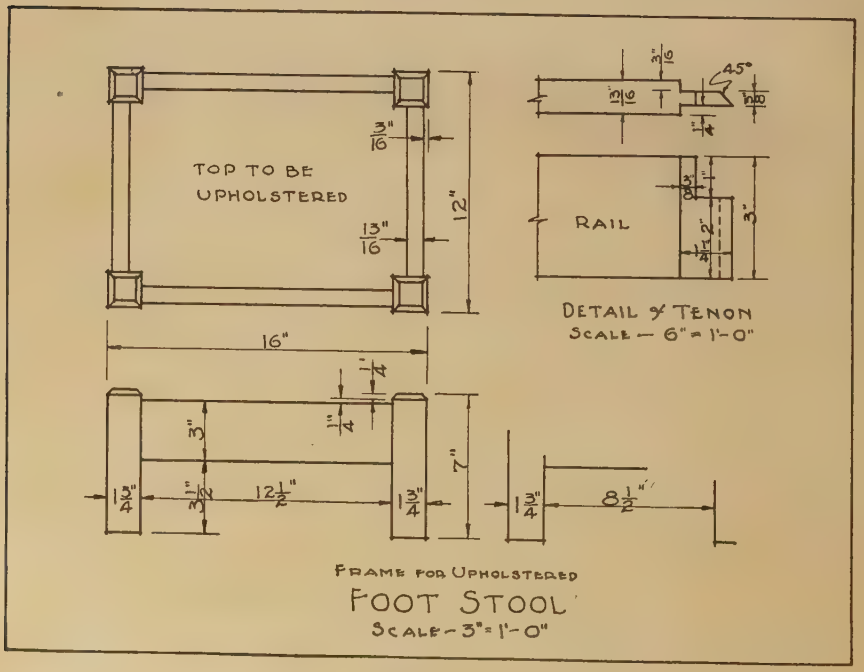


Plate 34A

ARCHITECTURAL DRAWING

Lesson 35

I. *Purpose*

To acquire some knowledge of the meaning of architecture and the work and training of a modern architect.

II. *General Information: Architecture and the Architect*

Architecture is the art and the science of designing and constructing buildings and other structures. It is one of the oldest of the arts of mankind, and the development of the arts of painting and sculpture had their beginnings in architecture; that is, they were used originally to decorate buildings. The history of architecture, beginning with the Egyptian, Greek, Roman, and continuing through the Renaissance to the modern European and American types, it is a most fascinating study. It is really a story of the development of civilization expressed in wood, stone, brick, and mortar.

To one who has an artistic as well as a technical inclination, the modern practice of architecture is one of the most interesting and satisfying of professions. An architect must first see a building in his mind's eye; he then studies it by making pictorial sketches, often in color. When the

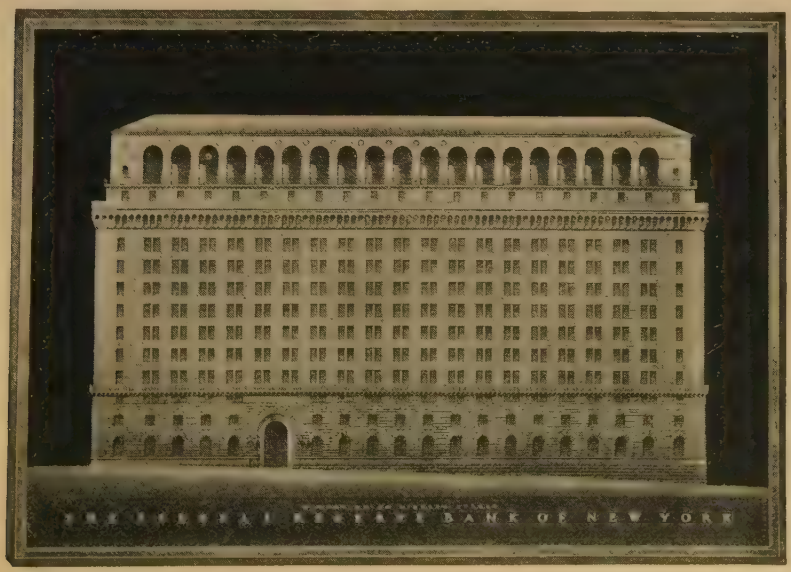


Fig. 39. Accepted design entered in a competition for the Federal Reserve Bank of New York, N. Y. (York & Sawyer, Architects)

design is completely satisfying to himself and his client, he makes an extensive set of working drawings, which are put in the hands of contractors and mechanics who do the work of construction. All of this work is subject to the architect's approval. Finally, when the building is completed, it stands as a permanent record of the designer's achievement.

Fig. 40. Rheims Cathedral (Photo, Ewing Galloway)

Few, if any, professions require as much in the way of ability, personality, education, and perseverance, as architecture. A generation ago many young men who were good draftsmen studied architecture on their own initiative, and when they had saved a sufficient sum of money they would establish businesses of their own. However, that time is past. It is now almost impossible to become an architect without having had college training, and many students now feel that their education is not complete until they have traveled in Europe and studied in Paris and Rome.

The successful architect must have artistic ability as a basis for design and drawing; he needs engineering and mathematical qualifications to

handle the problems of construction; business ability is required to handle that aspect of his affairs; a pleasing personality is an asset in meeting customers and dealing with contractors; and lastly, he should be a broadly educated and cultured gentleman.

In practice, few architects meet all the above requirements. Hence, it is a business in which there are many partnerships. One partner is usually an artist designer, another an engineer, and still a third a business man.

The young man who plans to enter architectural work usually completes all the training he can afford, and then enters the employ of an established architect of good reputation. He begins as a junior draftsman

Fig. 41. A modern office building. (Fisher Building, Detroit, Mich. Albert Kahn, Inc., Architects)

with a comparatively low weekly wage. Later he may advance to senior draftsman, chief draftsman, and hence to designer. He may continue as a hired designer, be taken into business as a partner, or strike out in business for himself. The period between college graduation and the establishment of an independent business is usually not less than five to ten years.

The drawings which the student will be asked to make in the lessons which follow are not *design* drawings, but *working* drawings, and it is well to keep in mind that there is a vast difference between an architec-

Fig. 42. An architect's rendering of a modern office building. (Drawing of the Fisher Building, Detroit, Mich., by Hugh Ferriss)

Fig. 43. Ruins of the Roman Colosseum, one of the finest examples of Roman architecture. (Underwood & Underwood)

tural draftsman and a fully trained architect. Most first-class established architects are members of the A.I.A. (American Institute of Architects). Many poorly trained men dabble in architectural drawing, and the public should be warned to make sure of a man's qualifications before retaining his services.

Sources for further study:

Price: *The A B C of Architecture.*

III. *The Problem*

Study the illustrations included in this lesson. (Figs. 39 to 44.)

Fig. 44. The Greek Temple of Theseus, one of the best preserved of the buildings of ancient Greece. (Photo, Ewing Galloway)

Lesson 36

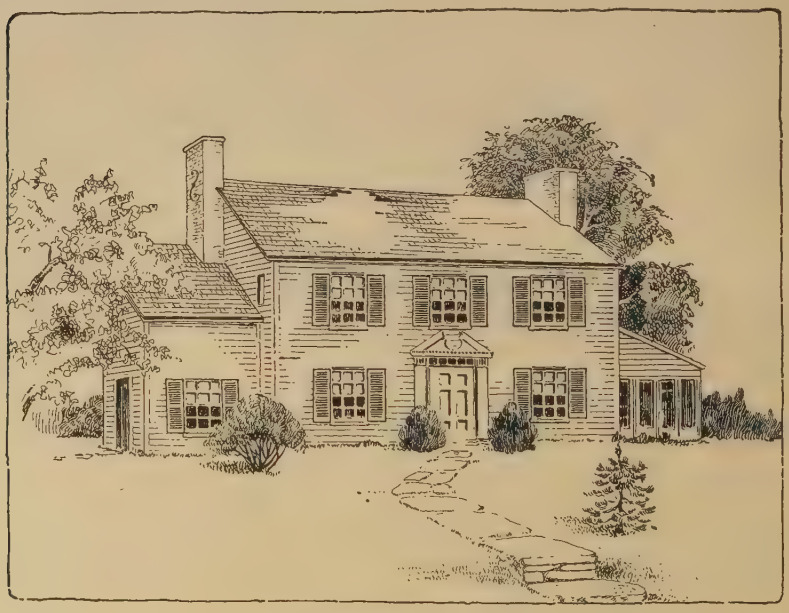
I. *Purpose*

To learn to recognize some of the common types of domestic architecture and to form some opinion about each.

II. *General Information: Types of Domestic Architecture*

Nothing is so apparent to the European traveler in America as our lack of appreciation of what is good and fitting in the design of our residences. Good design in houses is a matter of knowledge and taste, and not one of cost. In fact, there are many cases where the very things which have made a building expensive are also the ones which spoil the design.

In the following paragraphs, eight types of houses commonly seen are briefly described and illustrated. Study each sketch along with its accompanying paragraph.



New England Colonial House

1. *The New England Colonial* was developed in the New England colonies. It is suitable to northern climates having winter snows. It expresses economy, formality, and orderliness. Its outstanding characteristics are symmetrical balance in design; gable roof; narrow cornice; wooden shutters; wood-frame construction; wide clapboards; light-colored paint; and level site.

Dutch Colonial House

2. *The Dutch Colonial* comes to us from the early Dutch settlers in New York. It has many characteristics in common with the New England Colonial, as shown by the accompanying sketch. See if you can point them out. Its chief difference is in the roof, which is of the gambrel type. The

A Modern Adaptation of the Southern Colonial (*Architect's Small House Service Bureau*)

upstairs windows peek out through the roof by means of gable dormers. The low roof line gives this house a rather squatty appearance which imparts to it a more inviting and homelike effect than that of its New England relative. The large flat-topped dormers sometimes used in modern copies of this design are usually very ugly.

3. *The Southern Colonial* comes to us from the old plantation houses of the colonial South. This again has much in common with its northern sisters. The chief difference from the New England Colonial is its wide veranda or porch which was usually two stories high and supported by round wooden columns. It expresses the generous hospitality of the South. It should not be copied in northern climates.

English Country House

4. *The English Country House* is quite different from the three colonials. It has steep roofs, usually with twin gables. The exterior is brick or plaster and the second story is half timbered. The windows are always of the casement type, frequently arranged in groups. It expresses easy informality and is a very popular type of design for country homes, clubs, lodges, and the like. It is distinctly a house for northern and temperate climates.

5. The house showing the influence of *Italian Design* is intended for warm sunny climates. It has medium-pitch gable roofs, usually covered with tile. The exterior is plastered with a light-colored stucco of fairly

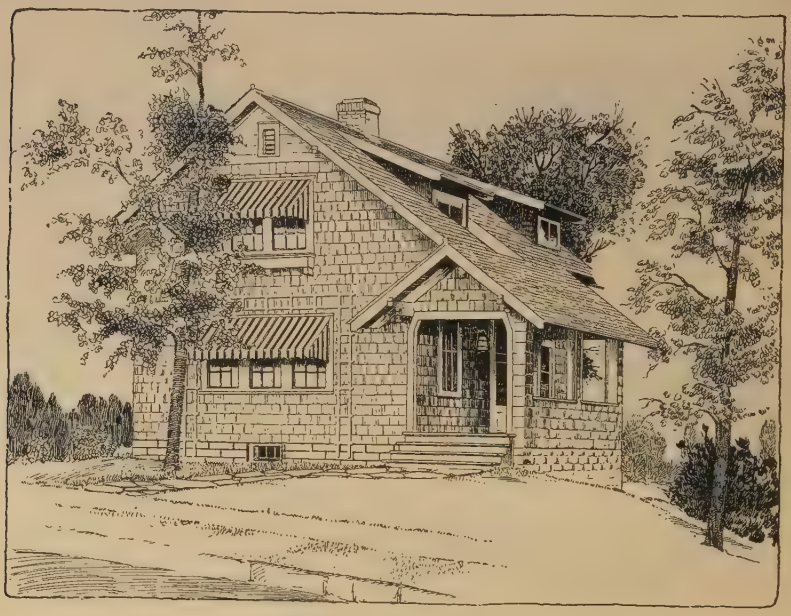
Italian Design

smooth texture. The windows are of the casement type. Balconies, columns, and arched openings are also common characteristics.

6. The *Mission* or *Spanish* house which has become so popular has many ancestors. The red-tile roofs, the iron railings, balconies, and patios

Mission or Spanish House

show the influence of Old Spain. The thick plastered walls and flat roofs come from the "adobe" structures of the southwestern Pueblo Indians. The missions of the early Spanish priests of the southwest are the direct parents of this design. Casement windows, awnings, and arched openings are usually used. This design was developed in the hot, dry climate of southwestern United States and probably has little place in cold or cool latitudes.



Western or Chicago Type

7. The *Western* or *Chicago* type of house was developed by the early settlers of the middle western states. Houses built by these people were constructed and planned hurriedly. Little or no thought was given to appearance. The chief concern was to erect houses which would provide shelter at a minimum cost. Practical but untutored carpenters and builders became accustomed to building these economical shells, and a few continue to be built. Some of its faults are: lack of symmetry in placing openings, windows too large for the size of the walls, structure too high for its width, narrow lap siding which adds to the appearance of height.

8. *The Cottage* became popular in city suburbs a number of years ago when people turned from the large rambling old houses to small one-story houses in which a housewife might easily do all of her own work. The first design of this type to become popular was the California Bungalow which with its poor proportions and unnecessary ornamentation presented

Colonial Cottage (*Chas. S. Keefe, A. I. A., Architect*)

an extremely displeasing appearance. The idea of the one-story cottage was sound, however, and now many small well-designed houses like the one illustrated on this page are being built. The one here shown is colonial in character. The mission style is also being used a great deal with this kind of dwelling.

The story of domestic architecture in the United States is a confusing tale, and we have not yet come to a happy ending. We hope that before many more years pass one or more new types will develop, which will be expressive of modern conditions and embody the basic principles of good design. There are those who believe the single-family residences will soon be used only by the wealthy and that the majority of people will live in apartments. What do you think about it?

Sources for further study:

Plan books, such as those of the Architect's Small House Service Bureau, 1200 Second Ave. S., Minneapolis, Minn., and 101 Park Ave., New York City.

III. *The Problem*

Use an unabridged dictionary and look up the meanings of the architectural terms used in this lesson.

In magazines or plan books, find at least one additional example of each of the six types of house designs described in this lesson.

Lesson 37

I. *Purpose*

1. To become acquainted with some of the facts and practices used in drawing the floor plans of a house.
2. To draw the floor plan of a small building.

II. *General Information: Floor Plans*

A plan in architectural drawing is a single top view of any part of a building. A floor plan is a top view of any one story of the building. It is drawn much like a horizontal section cut high enough above the floor to show all door and window openings.

From the standpoint of its use, the arrangement of the floor plans is the most important part of the job of designing a building. The elevations are important chiefly from the artistic point of view. However, it is to be remembered that a building should be one complete unit and that plans, elevations, site, equipment, and in fact everything connected with the building, must be kept in mind when planning any part of it; that is, the plan must fit the elevation and vice versa.

Because of the size of buildings, the plans must be drawn to a rather small scale (for house plans $\frac{1}{4}'' = 1'—0''$; and for very small buildings and for details $\frac{3}{4}'' = 1'—0''$). Other scales also may be used. The use of such a small scale makes it necessary to omit many of the less important lines in a drawing. This makes it necessary to use conventional symbols to indicate many parts. In Figure 46 are shown a few of the more common architectural conventions used in plans and sections.

The main rooms of a modern dwelling house are living room, dining room, kitchen, bedrooms, and bath. The best method of determining the size and arrangement of each room is to consider the size and location of the furniture to be placed in it.

In general, the living room should be in the form of a rectangle ($12'-0''$ x $18'-0''$ up to $18'-0''$ x $24'-0''$), with one end or side at the front of the house. The best exposure for this room is east or south. In cold climates, an entry or vestibule should be provided at the front door.

The dining room should be at least $12'-0''$ x $12'-0''$. It should join both the living room and the kitchen.

The kitchen should be smaller ($9'-0''$ x $12'-0''$ to $12'-0''$ x $14'-0''$) and carefully planned to provide the most efficient arrangement of equipment, such as sink, range, cupboards, etc. It should be so placed in the plans as to provide an attractive view from its windows, if possible.

Bedrooms vary in size from $10'-0''$ x $12'-0''$ to $16'-0''$ x $20'-0''$. They are best when placed in the corners of the house so as to provide cross ventilation through windows on two outside walls.

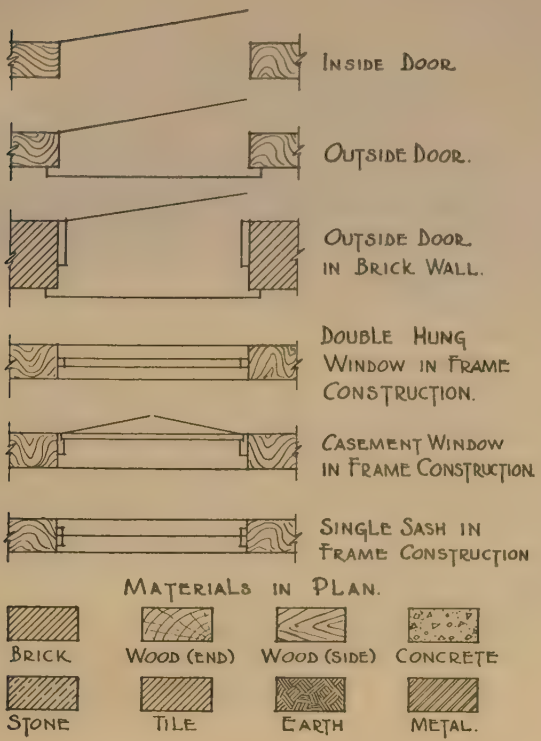


Fig. 46. Architectural conventions

Bathrooms may be as small as 5′– 0″ x 8′– 0″ but usually are 6′– 0″ x 9′– 0″ or 7′– 0″ x 10′– 0″. Some saving in plumbing may be achieved by locating the bathroom next to or above the kitchen.

Sources for further study:

Elwood: *Problems in Architectural Drawing.*

Catalog of the Architects' Small House Service Bureau, 1200 S. Second St., Minneapolis, Minn., and 101 Park Ave., New York City.

Current copies of such magazines as *The House Beautiful, Building Age and National Builder.*

III. *The Problem*

To copy one of the accompanying floor plans in Plates 37C, B, and A, and be prepared to explain what each line or convention stands for.

IV. *Suggestions for Procedure*

1. Locate on the sheet by drawing center lines.

2. Lay out, in order, outside walls, inside partitions, windows, doors, fireplace or chimney, cases, and other built-in fixtures.

3. Locate dimension lines and place dimensions. Dimensions on small-scale drawings should be accurate to the nearest $\frac{1}{8}$".

4. Note how the lines cross at intersections and how the dimensions are written above the lines. The technique used by the architectural draftsman is less exact and stiff than that of the machine draftsman. He strives for artistic effect as much as for mechanical accuracy.

In general, the architectural draftsman uses a lighter weight of line than others. He also omits many lines and dimensions on small-scale drawings. Too much information of a minor sort tends to make such drawings confusing rather than clear.

5. The width of windows on the plans are found by adding 4" to the total width of the glass. For example, in a 24" x 26" — 2 light, double-hung window, the glass is 24" wide, making the plan convention 28" wide. Or, in a 9" x 12" — 12 light, D.H. window, the glass is 27" wide and the convention 31".

6. Outside walls in wood-frame construction are usually drawn 6" thick. Actually they are slightly less than 6". See the detail drawings in Lesson 38 for the method of construction used in such walls.

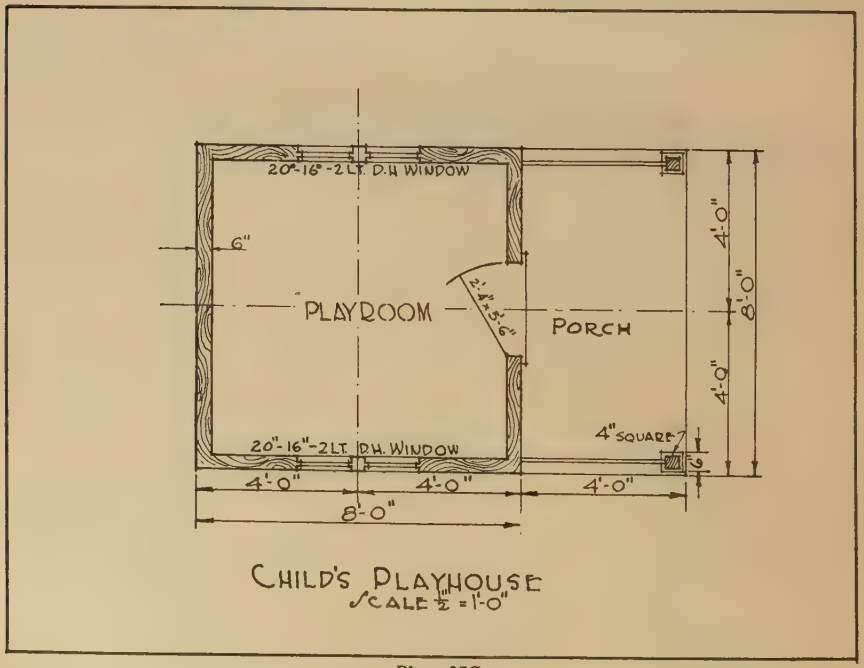


Plate 37C

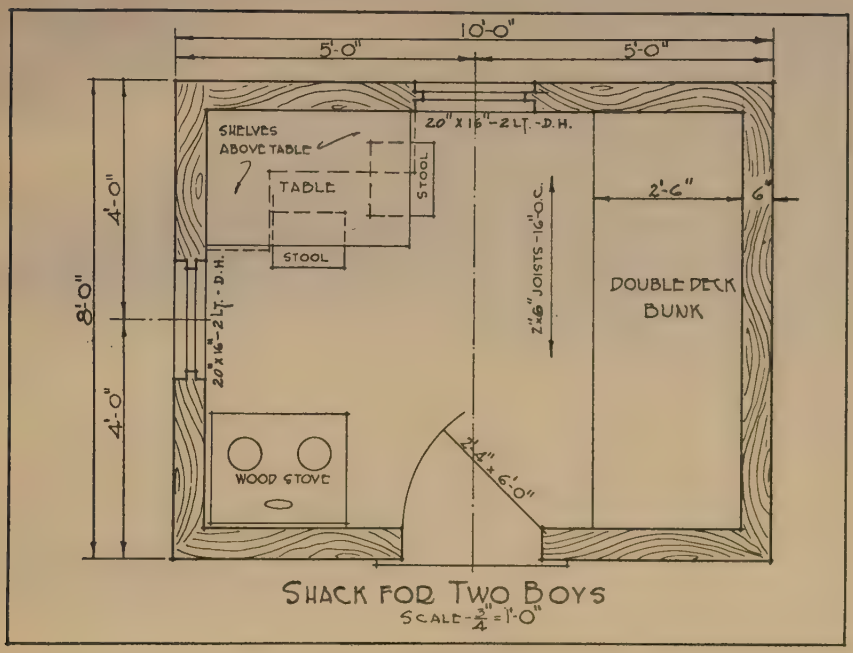


Plate 37B

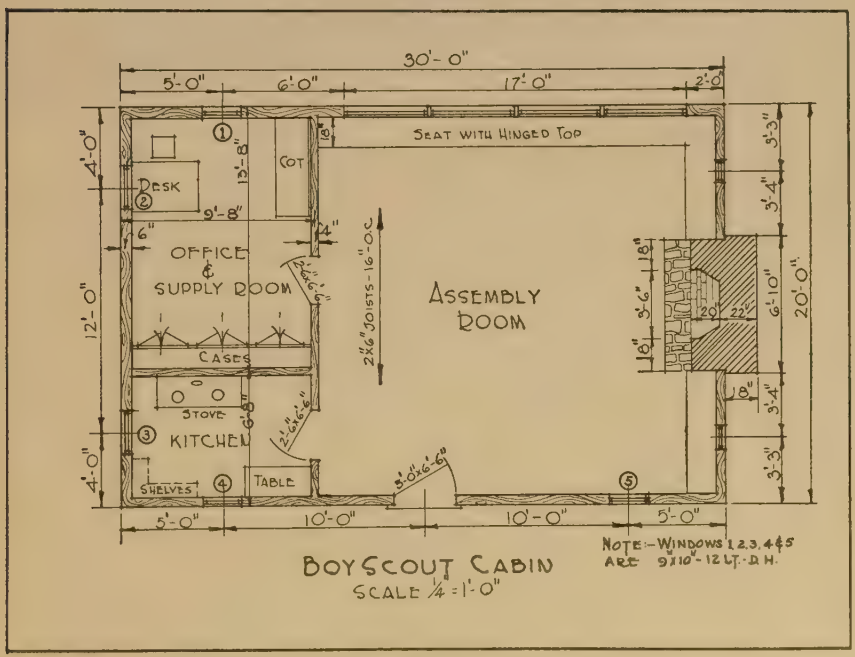


Plate 37A

Lesson 38

I. *Purpose*

1. To obtain a knowledge of some of the common elements of wood-frame house construction and the methods and materials used.
2. To draw a sectional detail of some part of a frame structure.

II. *General Information: Elements of Frame-House Construction*

In America the most important building material for homes has always been wood. It is, and will probably continue for some time to be, the cheapest and best-adapted material for this purpose. The National Lumber Manufacturers' Association has adopted this advertising slogan: *"Wood: Certified by Centuries of Service — Use It, Nature Renews It."*

Buildings built of wood are referred to as being of frame construction. The type of construction most used at the present time is what is known as the balloon frame, in which the framework is made up of a large number of small members (like 2 x 4's or 2 x 6's) fastened together with nails.

The architectural draftsman must know the various methods of joining these members in floors, walls, and roofs. He needs to know the standard sizes and shapes of stock lumber, and the characteristics of the different kinds of wood. Besides lumber, a multitude of other materials are used, such as roofing paper, tile, insulation, hardware, concrete, structural steel, brick, lath, plaster, sheet metal, etc., all of which may enter into the construction of a frame house.

In the limited space allotted to the subject in this book, it is impossible to do more than give an example or two of the facts about building materials which an architectural draftsman must have. Since lumber is the material most used, it is worth the student's time to learn a few facts concerning it.

Most of the wood involved in house framing is of the softwood class. Hardwood is used chiefly as interior finish, such as floors and woodwork. Lumber 2" or more in thickness and used for the framework of a building is called "dimension stock." Thinner lumber is referred to as boards.

In drawing, dimension stock and boards are usually drawn at the nominal or rated size. As a matter of fact, however, the actual sizes are always somewhat less. For example, a 2 x 4 is actually 1¾" x 3¾" and sometimes 1⅝" x 3⅝"; or a 1" x 8" shiplap board is really ¾" thick and has a surface width of 7¼". All such actual sizes, which are determined by the National Lumber Manufacturers' Association, must be known to the draftsman.

Furthermore, there are standard or stock widths and lengths of lumber. Other sizes cannot be obtained unless they are made to order.

Stock widths of softwood lumber are 2″, 4″, 6″, 8″, 10″, 12″, and 14″. Stock lengths are 8′, 10′, 12′, 14′, 16′ 18′, and 20′. In specifying a piece of lumber, the thickness is always written first the width next and the length last, as: 20 pieces 2″ x 6″ — 12′.

Many different tradesmen are involved in the construction of a house, but the carpenter is, no doubt, the most important one of the group. Masons, plumbers, sheet-metal workers, lathers, plasterers, painters, steam fitters, and concrete men are also concerned in frame-house work.

Sources for further study:

Brahdy and Landsman: *Construction Drawing.*

III. *The Problem*

To reproduce one of the construction details shown in Plates 38C, B, or A, or any other similar one. Study the drawings and learn the names of the parts.

IV. *Suggestions for Procedure*

1. In Plates 38C and 38B most of the dimensions are omitted. Since these are not standard, any dimensions satisfactory to your instructor are acceptable.

2. In Plate 38A, study the detail sectional view in connection with the small pictorial sketch. See if you can locate the corresponding parts.

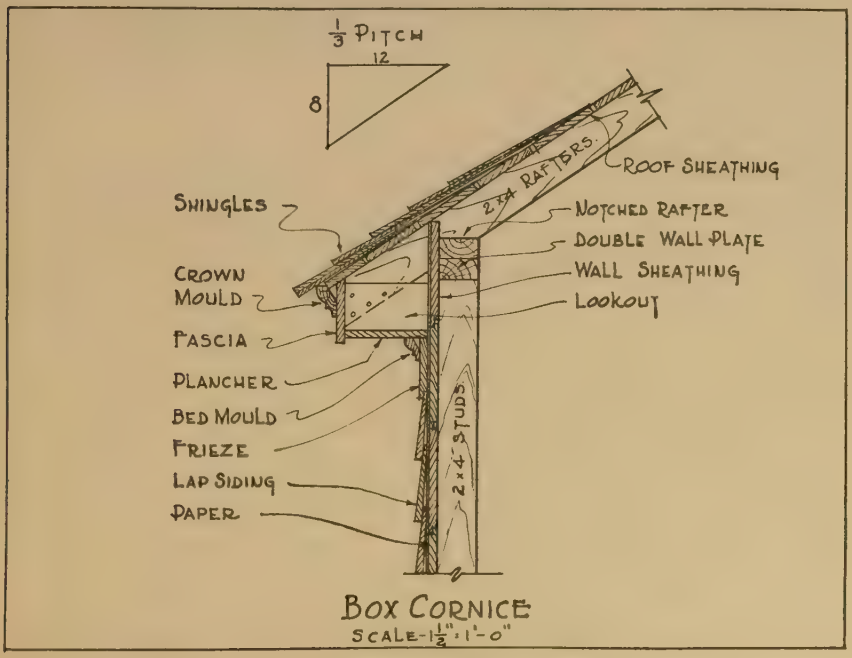


Plate 38C

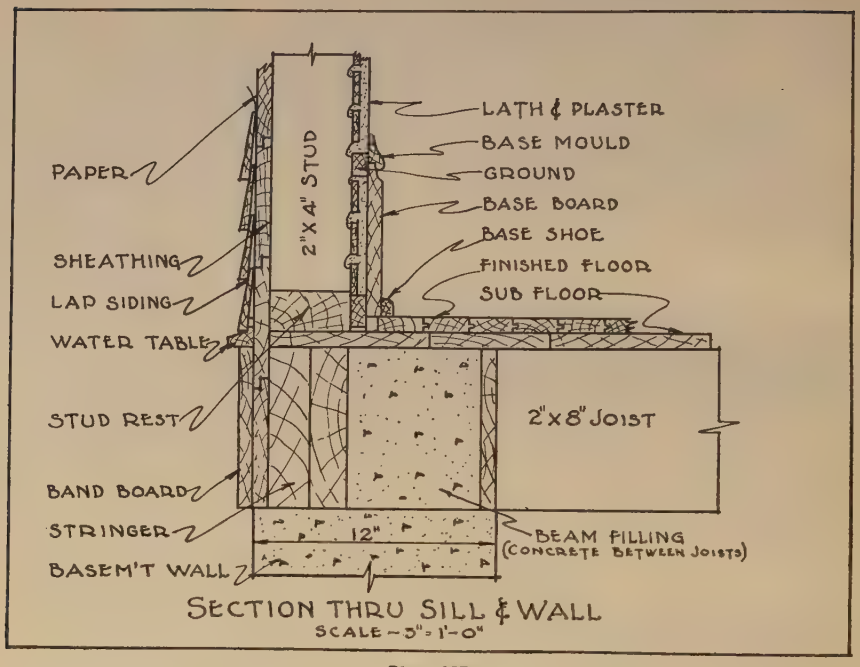


Plate 38B

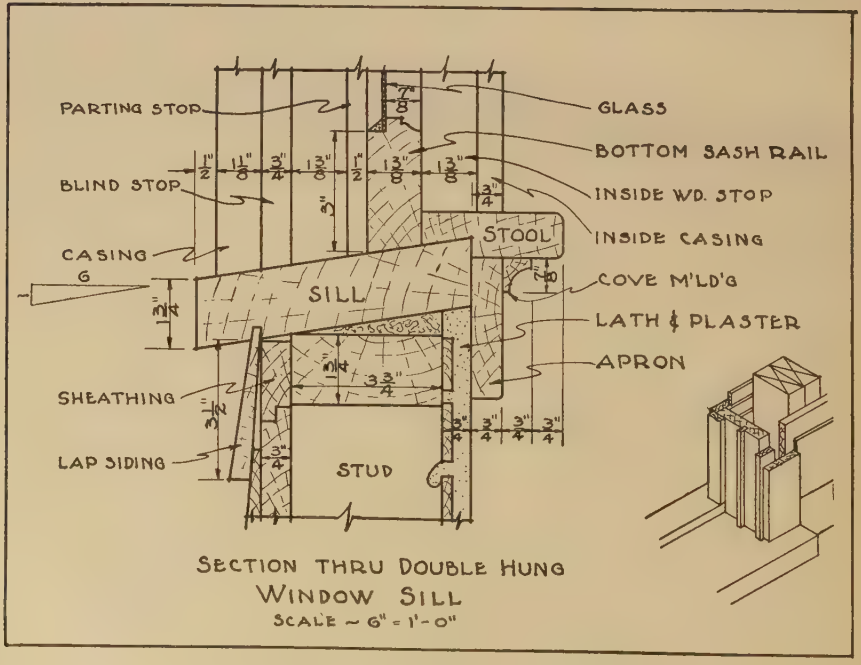
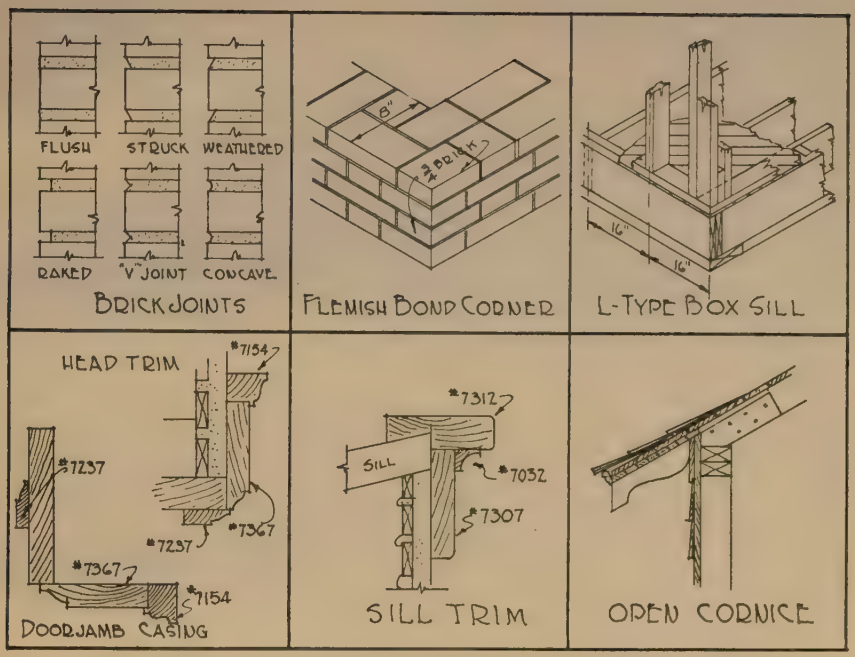


Plate 38A



Supplementary Plate 38

The detail drawings in the above plate are intended for study. Such study should make us more observing of the houses in which we live. Note the different ways of finishing mortar joints in brick walls. Try to find examples of each of these in the buildings you see from day to day.

The Flemish-bond corner shows how the brick are cut and arranged at the corner of a building.

The L-type box-sill drawing makes clear how the rough framework of a house is assembled at the lower corners.

The first two drawings in the lower row are details of the interior trim around windows and doors. Note the numbers, such as 7312. These are taken from the *Universal Millwork Design Book* No. 25. The moldings shown are standardized as to shape and size, and are illustrated full size in the above-mentioned book.

The open cornice at the lower right is so called because the rafter ends (rafter tails) are exposed. Cornices in which the rafter tails are closed in with boards and moldings are called "box" cornices.

Lesson 39

I. *Purpose*

1. To learn something about standard moldings and millwork, and to become acquainted with the requirements for drawing elevations.
2. To draw one elevation of a building.

II. *General Information: Standard Moldings and Millwork*

The use of standard parts has not been developed in the building industry to the same extent as in the manufacture of machines. However, it has received some attention. The standardization of lumber sizes, mentioned in a previous lesson, is one aspect of this. Moldings, window frames, sash, screens, doors, cabinets, balusters, and other building parts which can be made in a factory and hauled to the building job, are now made in standard styles and sizes. Such parts are spoken of as *standard* or *stock millwork*. Although it is still possible to have the millwork made to order, this is only done in the case of very expensive buildings. On the average, it costs about 50 per cent more for special millwork than for stock items.

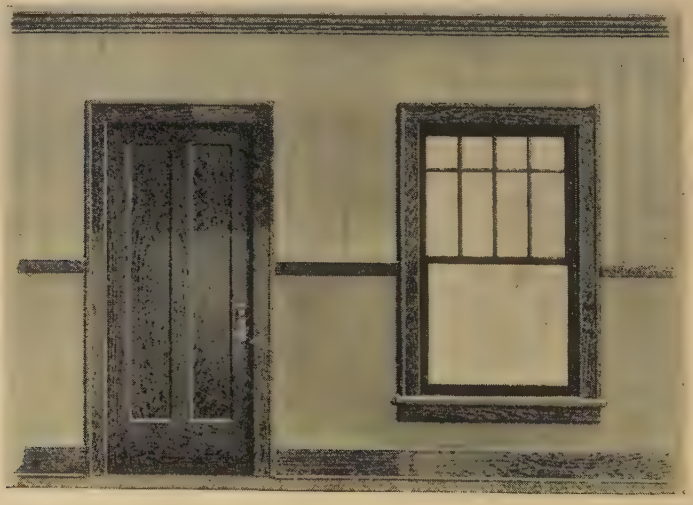


Fig. 47. Interior wall with moldings and trim. Note the variety of specially shaped pieces. These are all standard designs described in the Universal Millwork Design Book

The standard sizes and styles may be found listed and illustrated in the *Universal Millwork Design Book* obtainable at any lumber yard or woodworking mill. Every student should have an opportunity to see this book. The current copy in use in 1930 is No. 25. Moldings and interior finishing stock, such as casings, baseboards, etc., are indicated by number.

For example, the number 8060 indicates a certain cove molding in common use. Where stock moldings are used, it is unnecessary for the draftsman to draw details of them. Why?

Further standardization in building work is needed in order to reduce costs.

Elevations. An elevation is merely one of the orthographic views of an upright wall of a building. In addition to the floor plans, at least two exterior elevations should be provided in order to describe a building. A complete set of plans for a two-story residence usually includes three floor plans, four elevations, one or more sheets of details, and a sectional view.

From the standpoint of appearance and style, the elevations are the most important parts of the design. An otherwise well-arranged house may be greatly reduced in value and attractiveness by a poorly designed exterior. Only one skilled in architectural design should attempt to design exteriors.

However, the making of a working drawing after a sketch prepared by a competent designer is within the ability of any ordinary draftsman. A few general rules are worth mentioning here:

Tops of all window and door openings in the same story should be in line.

Window lights in small houses should be divided into small panes.

The top of the foundation wall should be from 6″ to 20″ above the finished grade.

Care should be taken not to make small houses too high for their size.

When a certain style, such as Dutch Colonial, is decided upon, it should be followed consistently throughout; that is, do not mix styles.

One of the most important elements in an elevation is the roof. There are many kinds of roofs. See if you can find out what each of the following is like: gable roof, gambrel roof, hip roof, shed roof, Gothic roof.

The pitch or slope of a roof is expressed as a fraction. For example, the small triangle drawn above the roof in Plate 38B indicates that the roof rises 6″ vertically for each 12″ that it extends horizontally. But since each side of the roof covers only one half of the total width or span of the building, the fraction expressing pitch is 6/24 or ¼. This roof, then, is said to have a ¼ pitch. Another way of expressing what is meant by pitch is as follows:

$$\text{Pitch} = \frac{\text{Rise}}{\text{Span}}$$

Sources for further study:

Seaman: *Progressive Steps in Architectural Drawing.*

Elwood: *Problems in Architectural Drawing.*

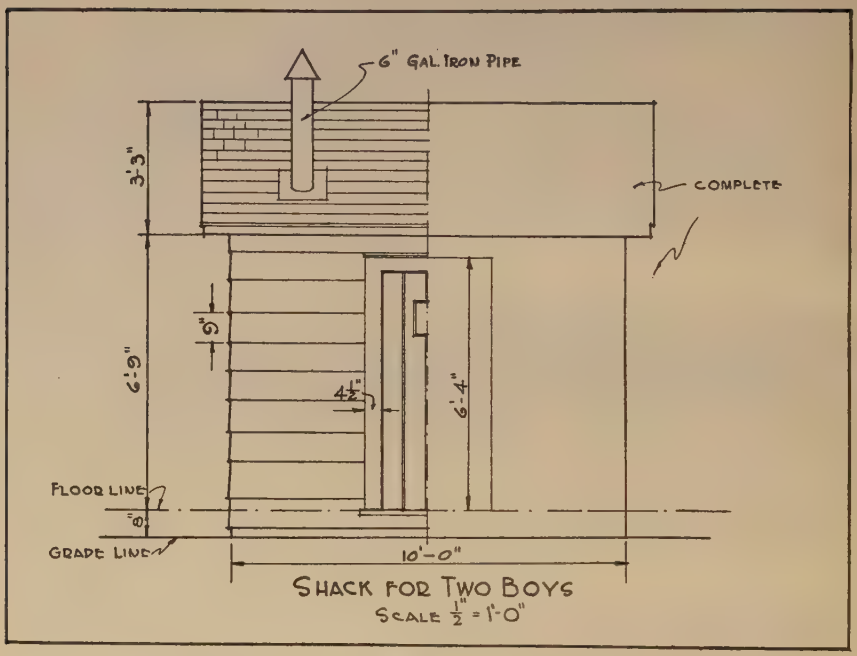


Plate 39C

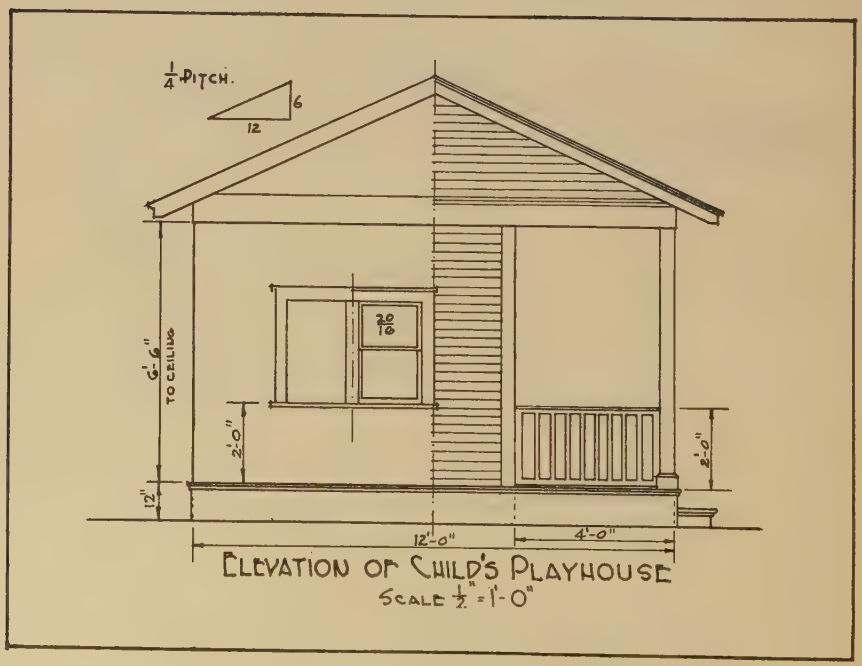


Plate 39B

III. *The Problem*

To study Plates 39C, B, and A, and copy and complete one of them. Or, to draw an elevation of some other similar building, either of your own design or from a picture.

IV. *Suggestions for Procedure*

1. Draw a line representing the grade or ground line.
2. Draw other light lines at the bottom of the floor, the top of the floor, at the ceiling line, and at the top of the roof.
3. Block out the main outlines.
4. Block out the windows, doors, etc.
5. Fill in details, as suggested in Plates 39C, B, and A.

Note: The location of the windows and doors and much other important information are omitted from the elevations. These data may be found in the plans in Lesson 37.

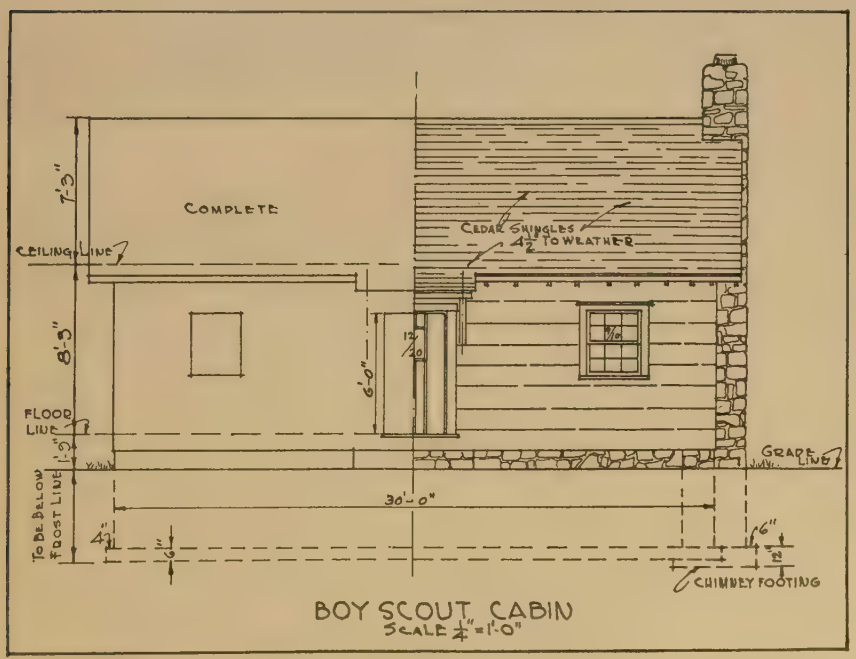


Plate 39A

Lesson 40

I. *Purpose*

To learn what steps are involved in building and financing a house.

II. *General Information: How to Build and Own a Home*

There are many things to be said in favor of owning one's own home, and it is the ambition of practically every American family to have a house and lot suited to its needs, free of financial encumbrances, and blessed with all the comforts which make it truly a home.

The first thing to decide in planning to build is the price-class of house one can afford. This, of course, is dependent upon the family income and the savings already made. A rough method of arriving at this price is to figure on a basis of the rent which the family pays for comfortable quarters. This may be done by multiplying the monthly rent by 100 to 150. For example, a family which pays $50 per month rent could probably finance a house costing from $5,000 to $7,500. Of course, this will vary in different cities and, also, for very small or very large incomes.

Once the price is decided upon, the next step is to decide on the method which will be used in paying for the property.

One of several methods may be used:

1. Pay cash. Few people are able to do this, but much better prices can be obtained if one has the cash available.

2. Save enough money to cover from 25 to 50 per cent of the total cost of the property and raise the remainder by borrowing money on a mortgage. On good property one can usually borrow about 50 per cent of the value on a first mortgage with interest at 5 to 8 per cent. Principal and interest usually are payable on the basis of a certain sum each year over a period of from five to ten years. If enough money cannot be obtained on the first mortgage, a second mortgage can usually be issued for about 10 to 25 per cent of the value of the property. The interest rate on such a mortgage will be higher, however, because of the greater risk to the lender.

In planning to finance a house in the above manner, one should not neglect to figure in the items of taxes, upkeep, and small improvements. It is necessary to be very careful to take all expenses into consideration, because failure to pay financial obligations when they are due may result in the loss of the property.

Next to paying cash, the mortgage plan is the most desirable method of financing a house. In order to be reasonably safe, one should have enough money to start with to cover from three eighths to one half of the total cost of the property.

3. Buy stock in a building and loan association. A building and loan association is a mutual stock company organized for the purpose of financing home builders. There are many variations in the working plans of such companies, too numerous and technical to be discussed here. In general, if a company is well established and reliable, the buying of such stock may be considered a safe and businesslike means of accumulating the initial payment on a home. After a certain proportion (usually about 30 per cent) of the total cost of the property one wishes to purchase has been paid in, the company will arrange for financing the remainder. One should seek the advice of his banker, however, before investing with any particular company.

4. Buy on a "contract." This method consists of saving in cash a down payment of about 10 per cent of the cost of the property to be purchased and of paying the balance with interest in monthly installments somewhat higher than ordinary rent. A common plan is to pay 10 per cent down and 1 per cent per month, plus interest. In the case of a house valued at $5,000, the purchaser would pay $500 down, leaving a balance of $4,500. The monthly payments on the principle would be $50. The interest for the first month at 6 per cent would be $22.50, thus making the payment $72.50. The following month the interest would be $22.25, and the total payment $72.25, and so on for 90 months or 7½ years.

Some prefer a payment of a uniform amount instead of one in which the interest decreases as the principal becomes smaller. In this case, one could retire the entire debt in the same length of time by making 90 monthly payments of $70.55 each.

The contract plan is the most unsafe and the most expensive method yet described. Under this plan the legal title to the property remains in the name of the seller until the purchaser has paid his entire indebtedness, or enough of it so that he can borrow enough on a mortgage to fulfill his contract. This arrangement makes it very easy for the seller to take the property back if the buyer fails to make his payments. Hence, he is in constant danger of losing all the money he has paid in. Sickness and loss of employment have caused many home buyers to default on their contracts and, if they have not lost their total investments, they have been forced to sell their contracts at substantial discounts.

Another undesirable feature of the contract plan lies in the fact that the real-estate operator or home builder who furnishes the money, usually takes an additional profit of from 10 to 20 per cent, which one might avoid paying if some other plan were employed.

When a plan for caring for the financial side of a building project has

been decided upon, the actual problems of obtaining a suitable house may be considered in detail. The first question that arises is, "Shall we buy or build?" There are many arguments on both sides of the question, which space does not permit us to discuss here. However, it may be said that, in a growing community where new houses are needed, one may usually get more satisfactory results by building than by buying a house which has been built for someone else.

In selecting a site, one should think first of the section of the city where price, class of people, natural surroundings, modern improvements, and promise of future development are most suitable. The particular site selected will usually depend on what is obtainable. In general, the lot should be not less than 40′ wide, and a 60′ or 75′ width is preferred; it should be of such a height as to slope gently from the house toward the street; eastern or southern exposure is to be preferred; and most important of all, the houses already built in the immediate district should be at least as good or better than the one to be built.

The house should be designed with the site in mind; that is, it should fit the contour of the land and the general surroundings. Many home builders do their own planning, but it is not advised. It always pays to employ a competent architect to design a building and supervise its construction. He will charge a fee of about 5 per cent of the cost of the building, but the services of a trained man will more than add that amount to the final value of the structure.

When the plans and specifications have been completed, the next most satisfactory step is to call for bids from a number of reliable general building contractors who specialize in residential work. One is not obligated to accept the lowest bid, but this is the common practice. The general contractor may sublet portions of the work, such as plumbing, electric wiring, plastering, etc., to specialists referred to as subcontractors. However, the direct dealings of the owner and architect are with the general contractor only.

If any portion of the work is not performed according to the plans and specifications, the owner and architect may require the contractor to do the work over, or forfeit a portion of his fee. It should be noted in this connection, also, that the more complete and exact the plans and specifications, the more accurate the bids will be and the less probability for disagreement on quality of materials and workmanship.

Sources for further study:

Catalog of the Architects' Small House Service Bureau, 1200 S. Second St., Minneapolis, Minn., and 101 Park Ave., New York City.

Lesson 41

I. *Purpose*

1. To gain some familiarity with the field of ornamental iron and bronze drafting and construction.
2. To make a drawing of some article of ornamental iron or bronze.

II. *General Information: Ornamental Metal Products*

A considerable industry has grown up in recent years in the manufacture of ornamental metal products. Bank grilles, gates, lighting fixtures, lamps, street markers, bronze tablets, statuary, building hardware, and fireplace equipment are only a few of the many products referred to in this discussion.

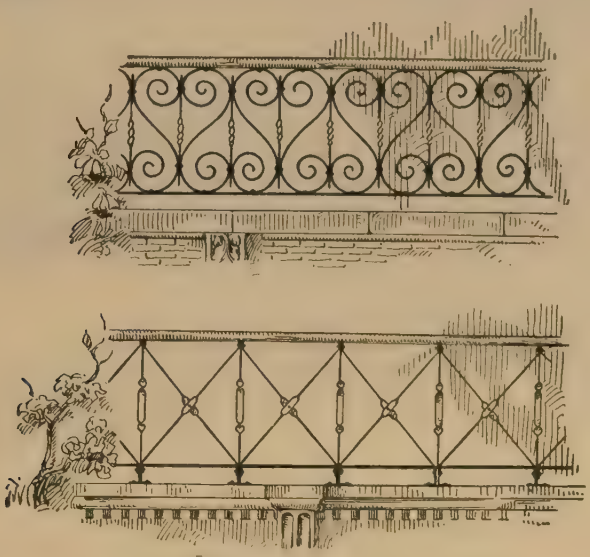


Fig. 48. Examples of wrought-iron railings

Since these products are ornamental, it can be readily seen that the designs from which they are made must be very skillfully done. Most of the drawing of this type is done at the factory. The drawings usually are full size and in pencil. Much of the work is done free-hand. The architectural technique is used, but the work is so specialized that a general architect usually makes only a small-scale drawing of ornamental metal parts to indicate the general idea of the design. The final full-size details are made by special draftsmen in the drafting room of the factory where the work is to be done.

Such a draftsman must be familiar with the properties of various metals, such as wrought iron, brass, copper, bronze, cast iron, and steel. He should also know the stock shapes and sizes available. In addition to a knowledge of materials, some familiarity with the machines and methods used in the shops is also essential. For example, he must know that bronze tablets and

statuary are cast in molds, that certain sizes and shapes of metal may be bent cold while others require heating, and that some wrought-iron work is hand forged, while others are stamped out with dies.

This type of work is very interesting to one with some practical training and an artistic turn of mind.

Sources for further study:

Catalog of the Flour City Ornamental Iron Co., Minneapolis, Minn.

III. *The Problem*

To copy and complete one of the drawings in Plates 41C, B, or A, or make a similar drawing of an original design.

IV. *Suggestions for Procedure*

1. Suggestions for other designs may be obtained by observation in home, school, office, or store. Literature and drawings may be had from firms specializing in ornamental work.

2. Note the shading in Plate 41A. The purpose is to give the effect of depth without using sectional views.

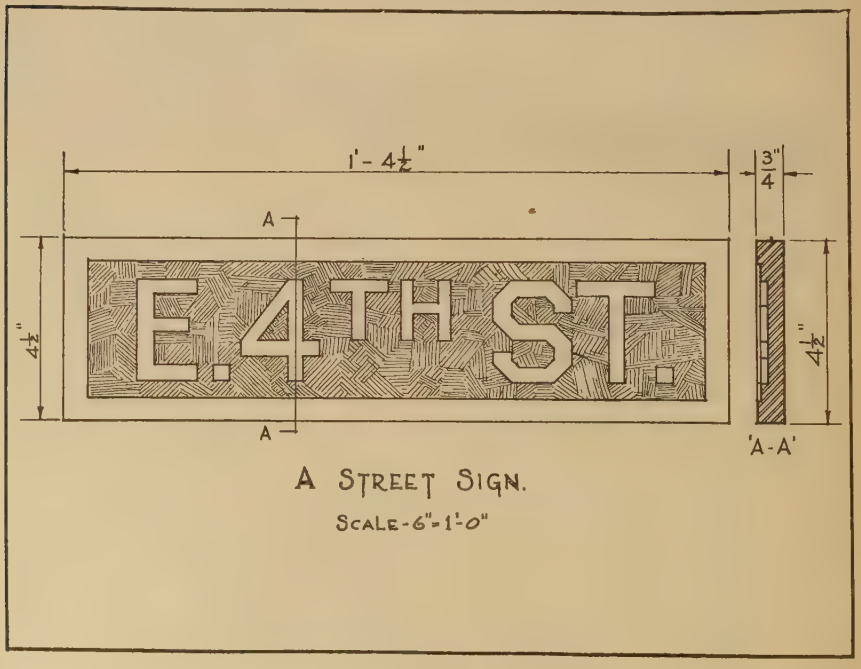
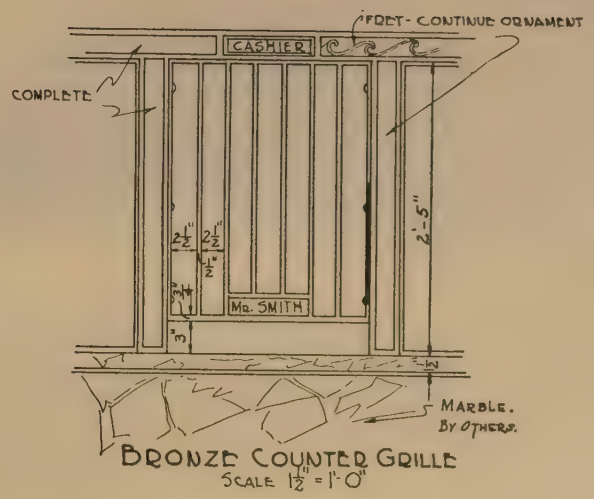


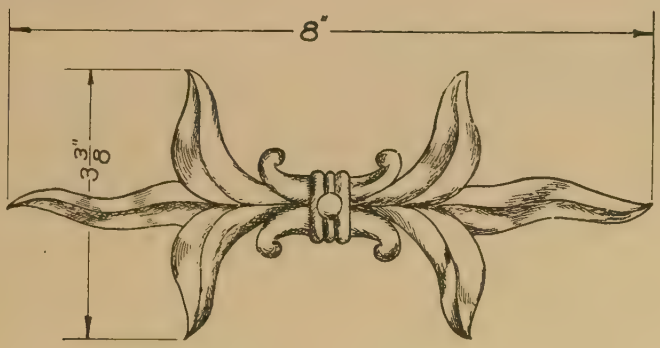
Plate 41C



BRONZE COUNTER GRILLE

SCALE $1\frac{1}{2}$" = 1'-0"

Plate 41B



CHIMNEY ANCHOR.

SCALE - FULL SIZE.

Plate 41A

Lesson 42

I. *Purpose*

1. To learn something about masonry as related to architectural drawing and design.
2. To make a drawing involving brick or stone bonds.

II. *General Information: Masonry Construction*

The first *permanent* building material used by man was, no doubt, stone. The stones were laid up roughly and the joints filled with clay. Stones were difficult to cut and handle because of the crude tools of the times. But the Babylonians found that certain kinds of clay when baked in the sun or fire became very hard. Brick made in this way was the first manufactured building material. Our knowledge of building and building materials has advanced a long way since that time, but brick is still one of the most popular and useful of all building materials for the exterior walls of better-class buildings.

We are accustomed to thinking of permanent buildings in terms of masonry materials, and it is through the use of these that architecture has had its greatest development. All the great examples of architecture have made use of masonry either in whole or in part. Even since concrete and steel have come into common use, a brick or stone facing is used to cover the structure and give it an attractive appearance. Furthermore, there is a marked tendency to use more and more masonry and less wood in the smaller buildings, such as small store buildings and residences.

Besides its greater strength and permanence, masonry has the added advantage of being fireproof. This is a very important factor in modern cities, in some restricted districts of which, nothing but fireproof buildings are permitted.

Brick, stone, tile, and other units of masonry are laid together in such a way as to result in a wall which will act as a single piece. The scheme for arranging the brick or stone units to produce the strongest wall and the most attractive appearance is called the "bond." A number of bonds are commonly used. These are illustrated in Plates 42C, B, and A.

Space does not permit a long discussion of masonry construction, but here are a few commonly used terms, the meanings of which will be worth looking up in the dictionary: arch; keystone; voussoirs; lintel; mortar; glaze; pilaster; quoins; stucco; rowlock.

Sources for further study:

Kidder: *Architects and Builders Handbook.*

III. *The Problem*

To study Plates 42C, B, and A, and copy one of them, or to make any drawing of a masonry unit which has the approval of your instructor.

IV. *Suggestions for Procedure*

1. At the option of the instructor, one of the four bonds in Plate 42C may be selected and drawn double the size illustrated. Sizes of bricks vary. The average is about 2″ x 4″ x 8″.

2. These drawings are not difficult, but a great many lines are involved. It is necessary to work rapidly.

3. Study the Flemish bond in connection with the pictorial view shown in Supplementary Plate 38 on page 151.

Questions

Which of these bonds do you think is most attractive? Which strongest? Which most commonly used in America?

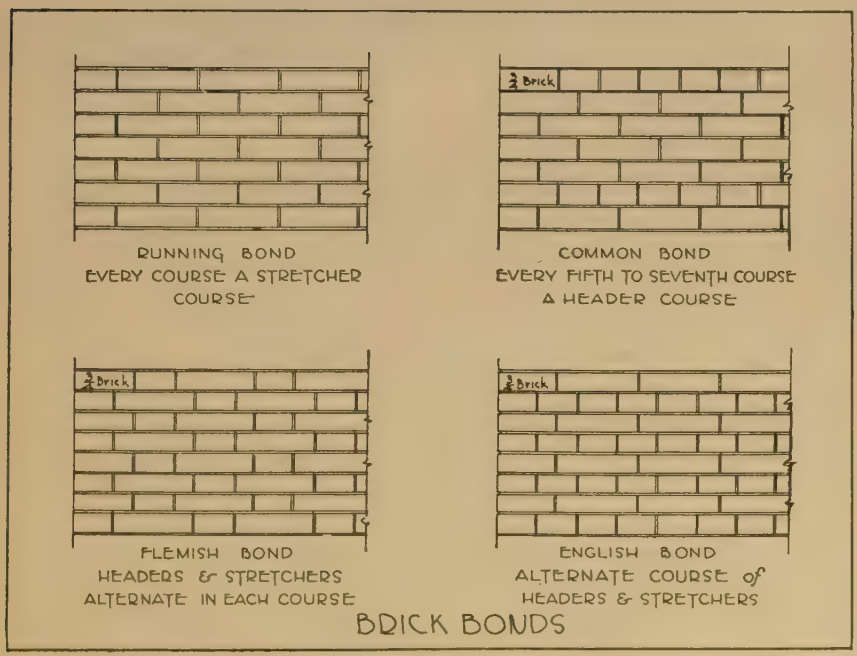


Plate 42C

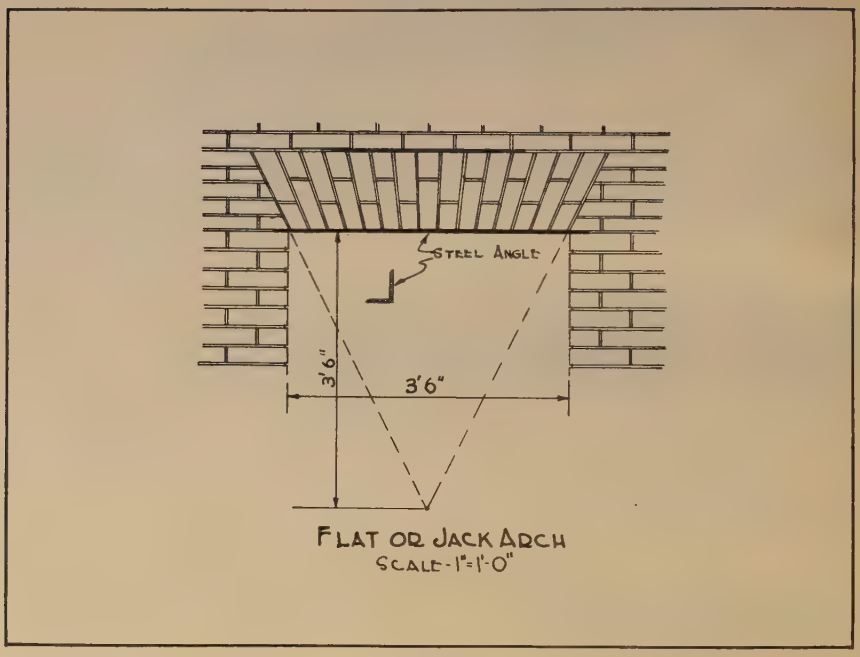


Plate 42B

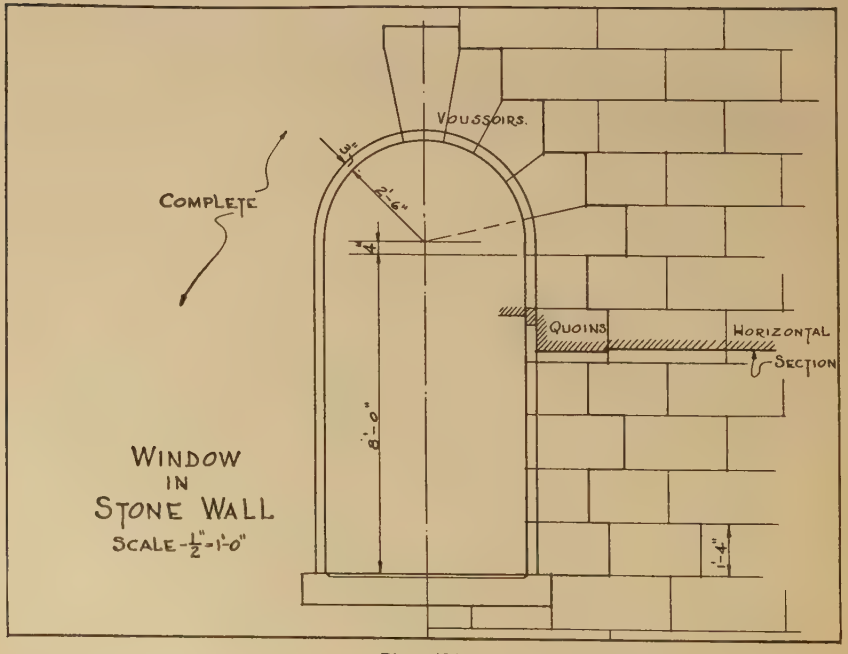


Plate 42A

Lesson 43

I. *Purpose*

1. To learn what a landscape architect is and the kind of work he does.
2. To make a plot plan of a piece of residential property.

II. *General Information: The Work of a Landscape Architect*

In the past, desirable sites for homes, institutions, and parks were selected from the wild, and merely cleaned up and improved. However, under present conditions, it is often necessary to use the less-desirable sites and improve or entirely revamp them. In addition to the growing scarcity of good natural sites, an ever-increasing amount of attention is being paid to the beautifying of grounds. The American people are beginning to appreciate and demand beauty in their surroundings more than they did a generation or two ago. Business men consider it good business to surround their factories and other properties with attractive lawns and shrubbery.

Fig. 49. An attractive formal garden. (Courtesy Portland Cement Association, Chicago, Ill.)

Formerly the task of designing landscapes was the work of the general architect. It has now become a specialty known as landscape architecture, and those who practice it are called "landscape architects." For one who has some artistic taste and a liking for trees, shrubs, and flowers, this is a very interesting profession, and one in which opportunities are increasing. The increasing development of golf courses and public parks alone offers attractive opportunities for work of this kind.

The work of the landscape architect requires a rare combination of personal talents. One must be at once an artist, an engineer, a horticulturist, and a business man. A number of good technical schools offer college

courses preparing for this work, and the student who is interested will do well to select the best school in his territory and, after completing his course, to work for an established practitioner for several years before setting out for himself.

Plates 43C, B, and A will give the student some idea of the kind of drawings landscape architects make to represent their designs.

III. *The Problem*

To copy one of the drawings in Plates 43C, B, and A, or to make a similar drawing of the landscape around your own home as you would like to have it.

IV. *Suggestions for Procedure*

1. Avoid too many or too heavy lines.
2. Block in the main features and fill in the details later.
3. Note how different types of vegetation are represented.

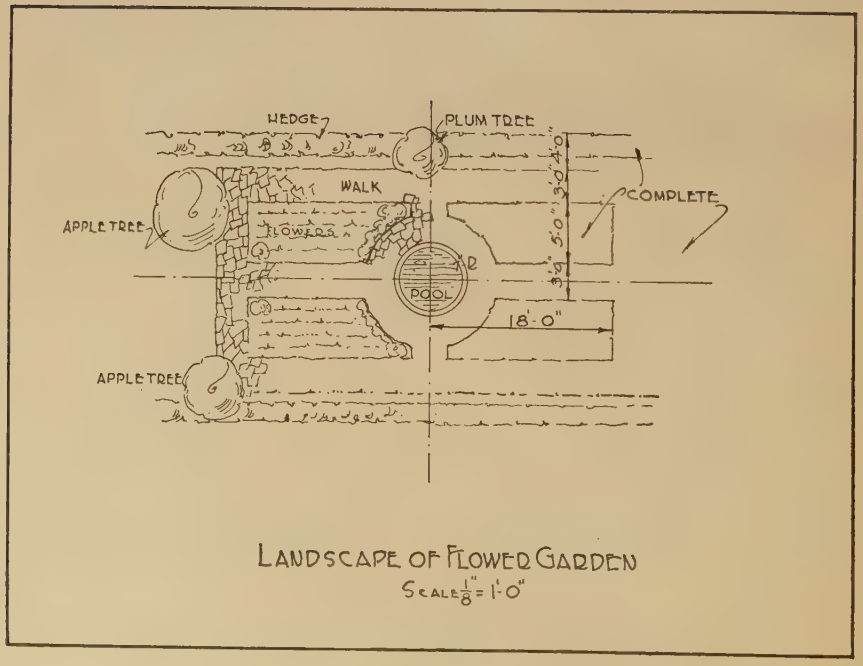
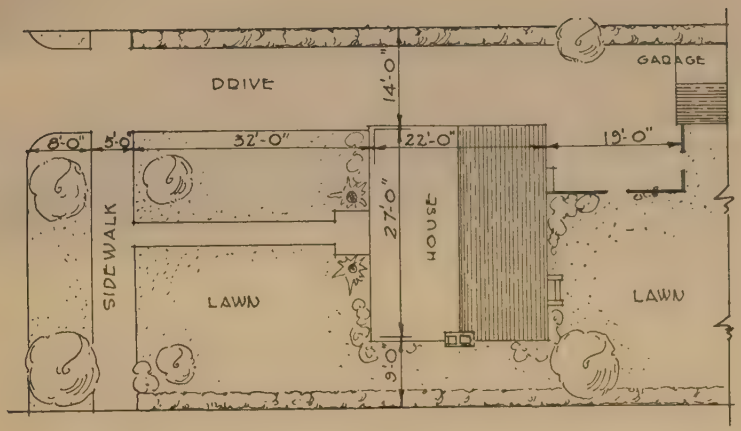
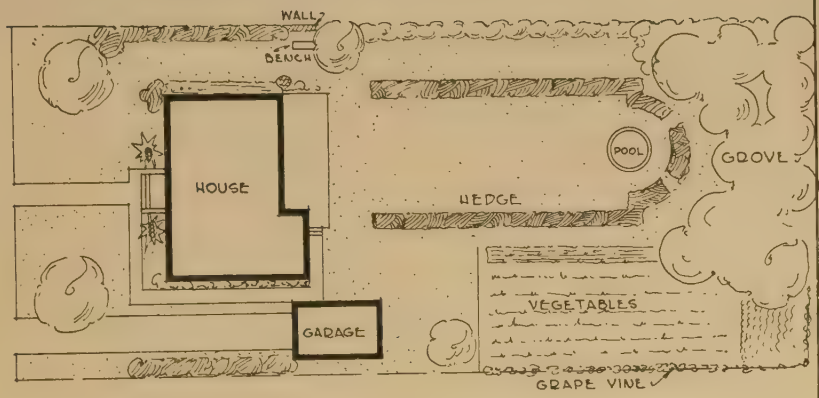


Plate 43C



LANDSCAPE OF FIFTY FT. LOT
SCALE $\frac{3}{32}$"=1'-0"

Plate 43B



LANDSCAPE LAYOUT FOR A LOT - 50 x 110
SCALE $\frac{3}{32}$"=1'-0"

Plate 43A

Suggestive Test 5

Directions: Each item in the right-hand column below is related to one item in the left-hand column. Show this relationship by placing the number of each item in the right-hand list in front of the related item in the left-hand list. For example, "glass" is related most closely to "sash," and "lath" to "plaster."

____	brick	1. glass
____	roof	2. frieze
____	wall	3. bond
1	sash	4. wall plate
____	interior trim	5. baseboard
____	wall sill	6. lath
____	foundation wall	7. rafters
____	cornice	8. studding
6	plaster	9. joist
____	door	10. jamb
____	floor	11. footing

Note to the teacher: Besides lists of related pairs, such as illustrated above, another useful type of matching question may be devised by making a sectional view on the blackboard, of some detail of construction such as a cornice, sill, or window frame. Number the parts, and provide the students with lists of the names of the parts. Direct them to place the numbers shown in the drawing before the corresponding names. True-false, completion, or multiple-choice questions may also be prepared on this section.

MAP DRAWING
Lesson 44

I. *Purpose*

1. To learn something about maps, and how and why they are drawn.
2. To draw a map of a city block.

II. *General Information: Maps and Map Drawing*

Maps are drawings of portions of the earth's surface. They may vary in size and importance from small maps of city lots to those which show the entire surface of the earth. Maps differ from other drawings in that one view only is usually used, and the drawing is made to a very small scale. Many special conventions are used.

We are all familiar with the uses of maps for locating the positions of cities, states, rivers, mountains, lakes, and the like. They are used as an aid to travelers on both land and water and in the air. Maps also provide valuable records in showing the boundaries of properties, such as farms, lots, mines, explorers' discoveries, and so forth.

A study of the development of map making over a period of several hundred years past, is an interesting one indeed. The old maps were very inaccurate and incomplete but, nevertheless, useful in their day. They were made to appear less incomplete by filling the blank spaces with pictures of animals, birds, and trees.

Since engineers have become more proficient in surveying and the world has become more densely populated, our maps contain so much information that it is often necessary to draw several maps of one area. Each of these gives a different type of information. For example, we have road, railroad, relief, political, military, contour, and historical maps, as well as many other special types.

Sources for further study:

French: *Engineering Drawing,* Chap. XVI.

III. *The Problem*

To study and copy one of the maps of city blocks, shown in Plates 44C, B, and A, or to make a similar map of the block in which you live.

IV. *Suggestions for Procedure*

1. Observe how the lots are numbered.
2. When lots are the same size, it is not necessary to give the dimensions of each one.
3. Sometimes lots are sold by the front foot, so it is important that the frontage or number of feet bordering on the street be given.

4. Direction is important on a map. This is indicated by the arrow pointing north.

5. The lettering used here is the same as learned by the student in his previous lettering. In actual practice, a special letter is used on maps.

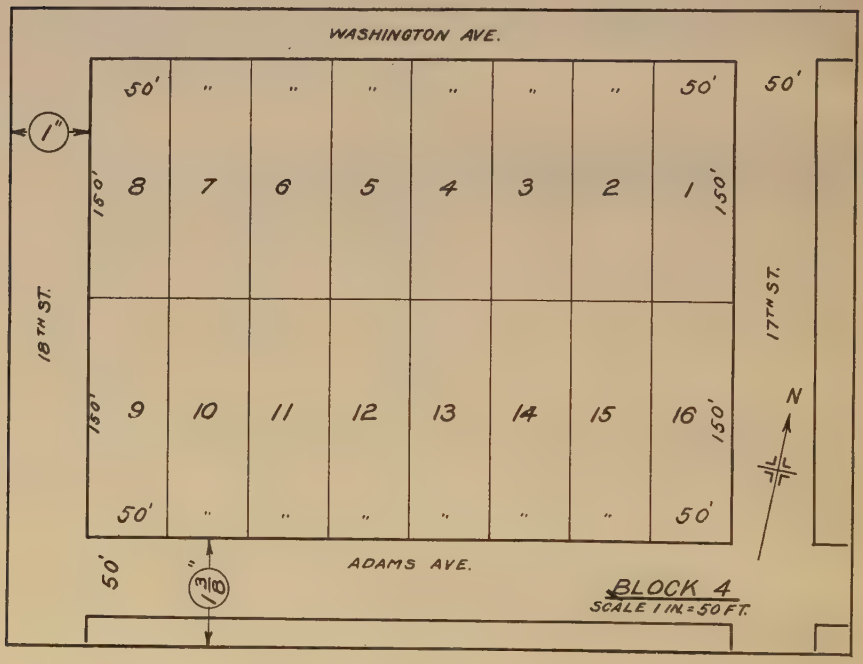


Plate 44C

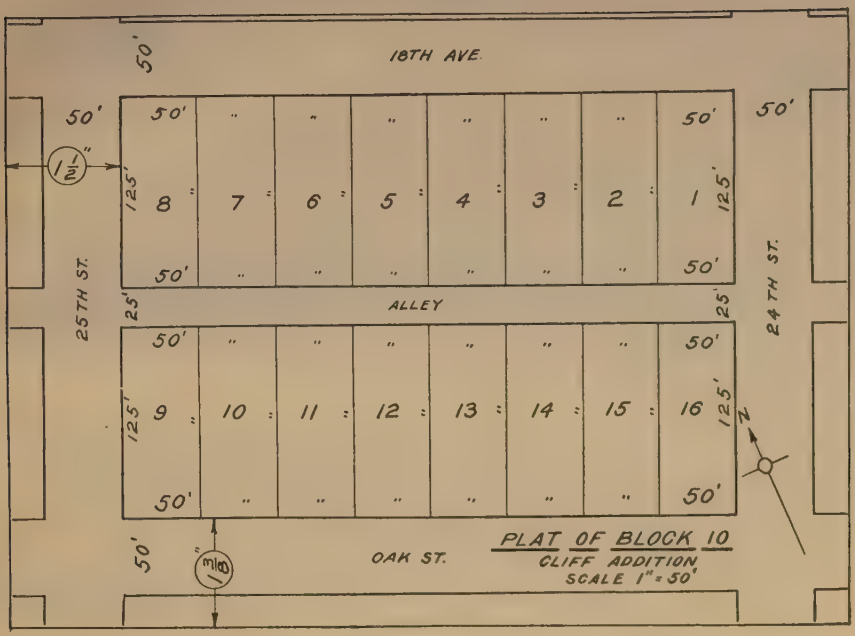


Plate 44B

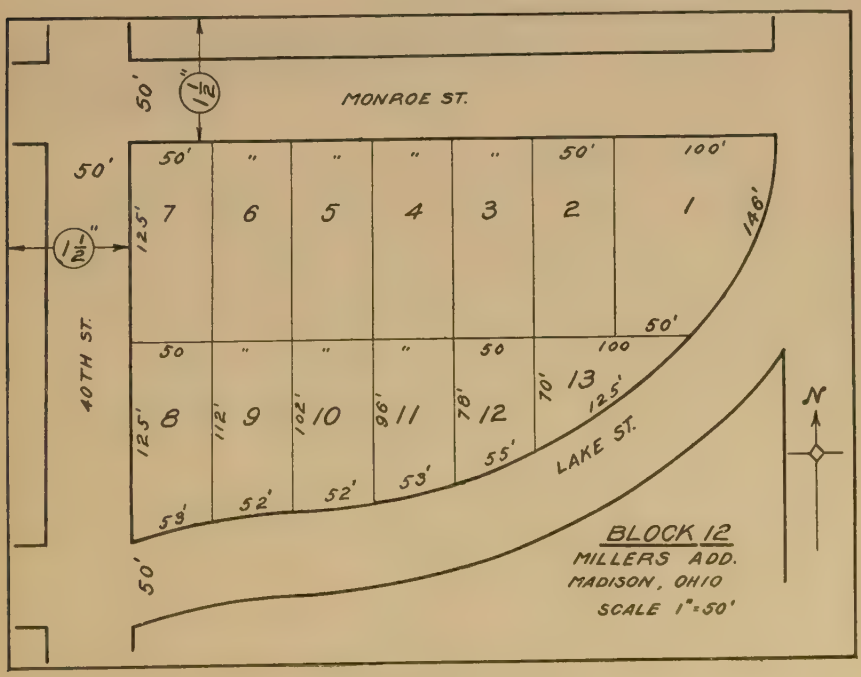


Plate 44A

Lesson 45

I. *Purpose*

1. To learn about the work of a civil engineer and its relationship to map drawing.
2. To make a drawing of a section of a city.

II. *General Information: The Civil Engineer and the Topographical Draftsman*

The civil engineer is the man who makes the measurements and gathers most of the information from which maps are made. By the use of special surveying instruments he is able to do this very accurately (look-up transit, Y level, stadia rod, and surveyors' tape). He must be skilled not only in the uses of these instruments, but he should also be a good mathematician in order to make the necessary calculations. A knowledge of trigonometry is especially necessary.

Sometimes measurements cannot be made directly, as across a body of water. In such cases measurements are obtained indirectly by projecting lines around the lake or marsh, and finding the desired distance across by making calculations. In many places, the compass needle does not point directly north. In these cases, a table of corrections is used. In projecting lines over long distances, the curvature of the earth causes an error which also must be corrected.

All this will indicate to the student that the civil engineer must be a man with much technical training. For best results, he should be a graduate of a four-year engineering course. No one should attempt such a course who finds mathematics difficult. The work of such an engineer is divided between outdoor and office duties. The fieldwork is rather strenuous and requires a good physique. The office work is mostly drawing and figuring.

Of course, it should be noted that civil engineers do not always do surveying work on roads, railroads, real estate, government surveys, and the like, but such work is typical.

Sources for further study:

French: *Engineering Drawing,* Chap. XVI.

III. *The Problem*

Make a map of a section of a city or village. One of the drawings in Plates 45C, B, or A may be copied.

IV. *Suggestions for Procedure*

1. The lines around the blocks represent the edges of the lots.
2. Note the street-car track in Plate 45B, and the railroad in 45A.
3. The line representing the edge of the block at the bottom and the right, are often made heavier as in this case.
4. In Plate 45C, the blocks are 200′ x 300′, and the streets are 75′ wide.
5. In Plate 45B, the blocks are 300′ x 600′, and 300′ x 500′. The streets are 100′ wide.
6. In Plate 45A, the square blocks are 160′ x 160′, and the streets are 60′ wide.

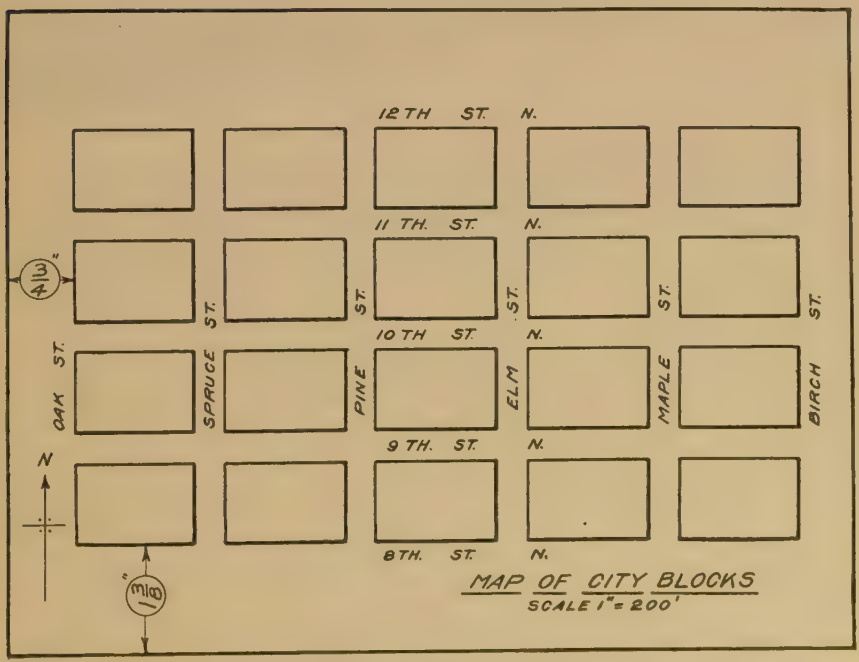


Plate 45C

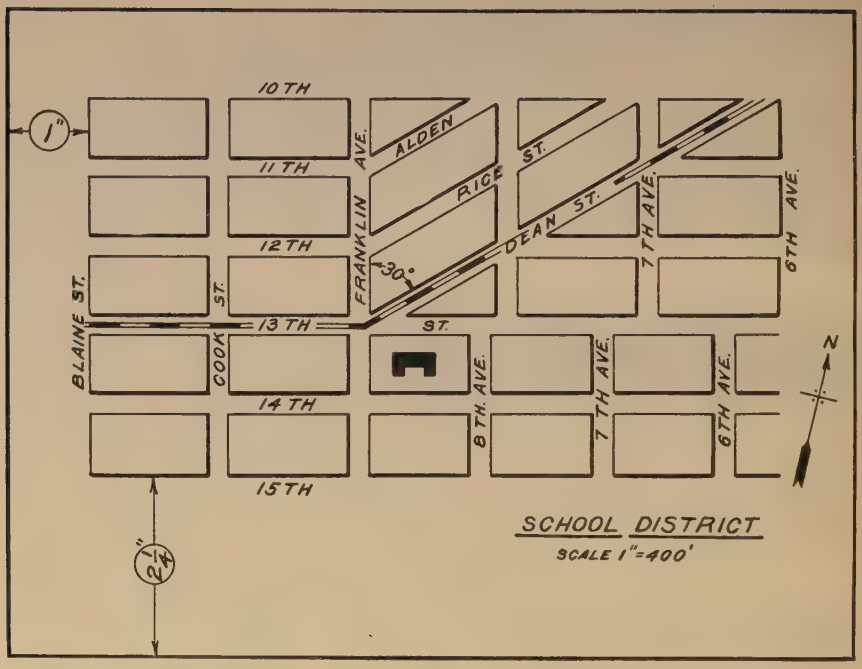


Plate 45B

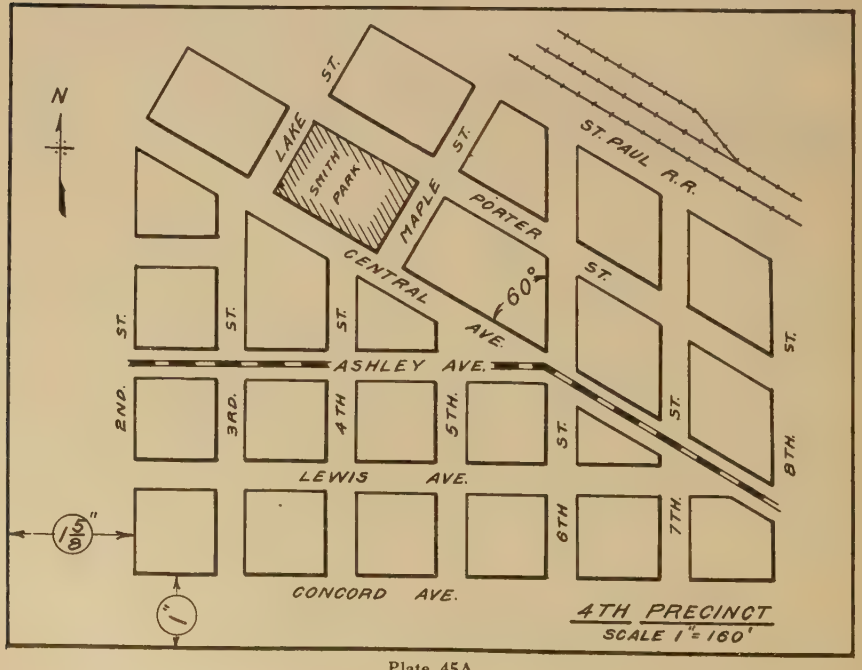


Plate 45A

Lesson 46

I. *Purpose*

1. To gain some familiarity with conventional topographic symbols.
2. To draw a map illustrating the use of some of these conventions.

II. *General Information: Conventional Topographic Symbols*

In map or topographical drawing, as in other types of graphical representation, many special symbols are used. Just as a machine thread or a double-hung window are represented in conventional ways, so in map drawing, special symbols are used to show water, mud, marshes, hills, sand, railroad tracks, highways, embankments, oil wells, different kinds of trees and vegetation, as well as dozens of other features.

These symbols are not wholly standardized, and it is often necessary to invent new ones in special cases. Hence, it is always desirable to include on a map a legend showing the names of the symbols used.

Sources for further study:

Maps obtainable from the U. S. Geological Survey, Washington, D. C.
French: *Engineering Drawing,* Chap. XVI.

III. *The Problem*

To study Plates 46C, B, and A, and copy one of them, or to make a similar drawing of another tract.

IV. *Suggestions for Procedure*

1. In Plate 46C, the light lines represent areas one mile square, commonly called "sections." How many acres in a section of land? The heavy lines show roads. The water lines are to be made free-hand.

2. In Plate 46B, the sections are divided into quarter sections by dot-and-dash lines.

3. In Plate 46A, the small squares represent sections. The large 3″ squares represent townships. There are 36 sections in a township. Note how the sections are numbered.

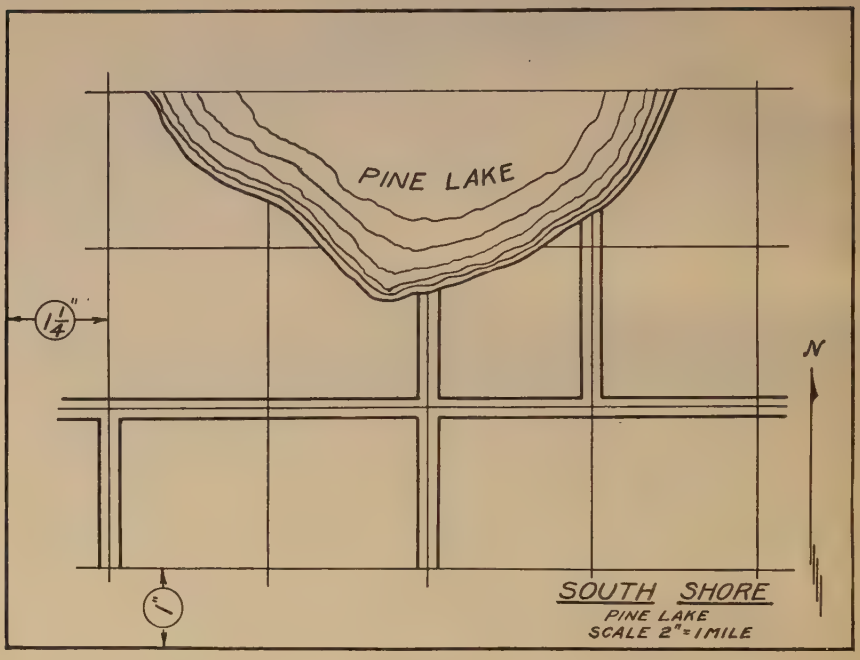


Plate 46C

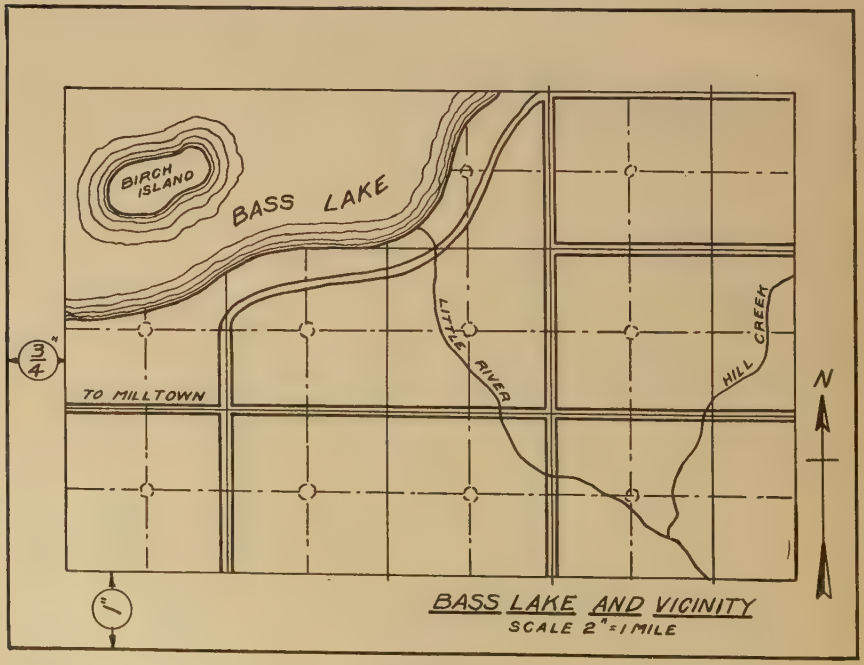


Plate 46B

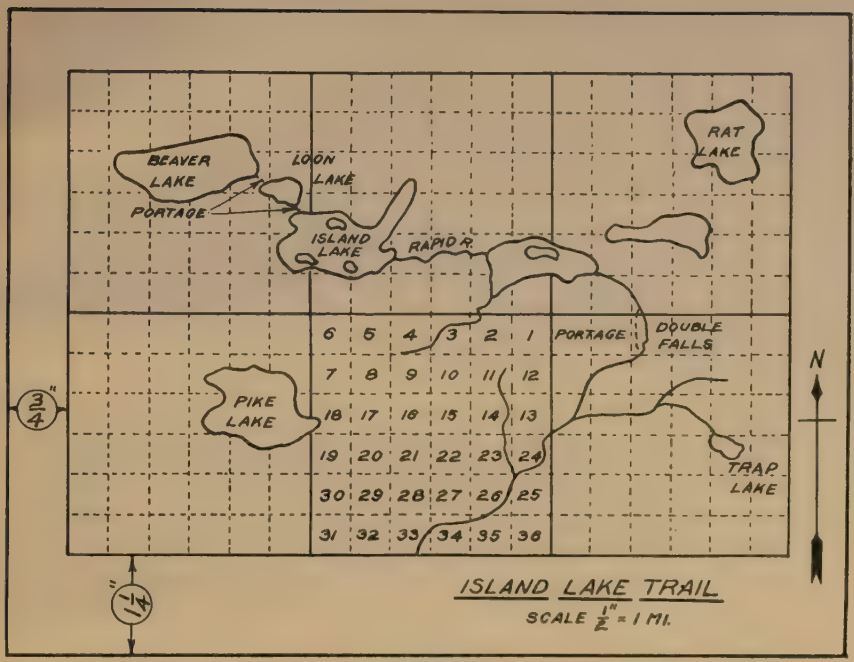


Plate 46A

Fig. 50. A special map for aviators (Courtesy Army Air Corps, War Department, Washington, D. C.)

Lesson 47

I. *Purpose*

1. To learn the meaning and uses of contours and profiles.
2. To become more familiar with such maps by making a contour map of a simple relief.

II. *General Information: Contour Maps and Profiles*

As explained in Lesson 44, maps are single-view drawings. However, it is often necessary to show the third dimension; that is, the relief or irregularities of the surface. Hills, valleys, lakes, ravines, and embankments may be represented in detail in two ways. On maps, the elevation (height) of all important points may be indicated by contour lines. On contour lines, all points are of the same elevation. If one were to walk around a hill on a contour line, he would go neither up nor down but would remain always on the same level. These contour lines are drawn at intervals of from one to several hundred feet, depending upon the scale of the drawing. The elevation of each line is marked upon it. Elevation is usually expressed in terms of number of feet above sea level. On maps of small areas, as of a golf course for example, any point such as the surface of a lake may be selected as the zero point. The shore line of the lake would then be the zero contour line.

In making contour maps the surveyor, by the use of his instruments, locates and finds the elevation of all important points, and then draws lines through all points of the same elevation.

Another more descriptive device for representing surface contour is the profile. A profile is merely a vertical section taken along a given line. It differs, however, from the ordinary sectional view in that the vertical scale is exaggerated or, in other words, vertical distances are drawn to a larger scale than the horizontal ones. An inch on the horizontal scale usually represents about five times as much distance as an inch on the vertical scale. Profiles are used in representing sewer and road work, grading, railroads, and to some extent in geographical work.

Sources for further study:

French: *Engineering Drawing*, pp. 316–317 and 325–326.

III. *The Problem*

To study Plates 47C, B, and A, and to copy one of them, or to make a contour drawing of a portion of ground with which the student is familiar.

IV. *Suggestions for Procedure*

1. Locate points on the contours where the most abrupt changes in direction appear.
2. Connect these points with lines drawn free-hand.

Questions

1. Which of Plates 47C, B, and A is drawn to the smallest scale? Which is drawn to the largest scale?
2. How do the lines representing water differ from the contour lines?
3. In Plate 47C, how would you know which were hill and which hollow if they were not marked with the words?
4. In Plate 47B, why are the contour lines closer together on one side of Otter Creek than on the other?

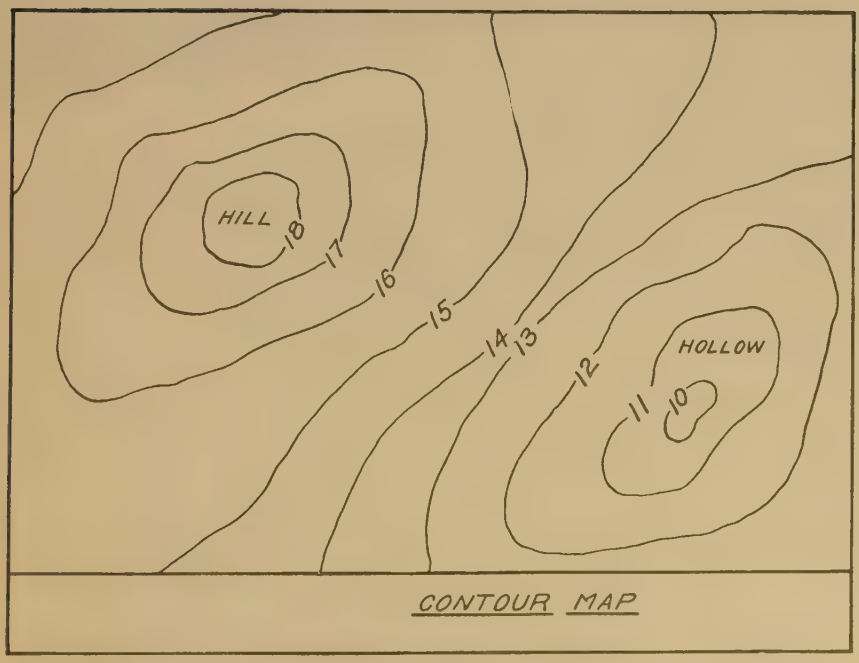


Plate 47C

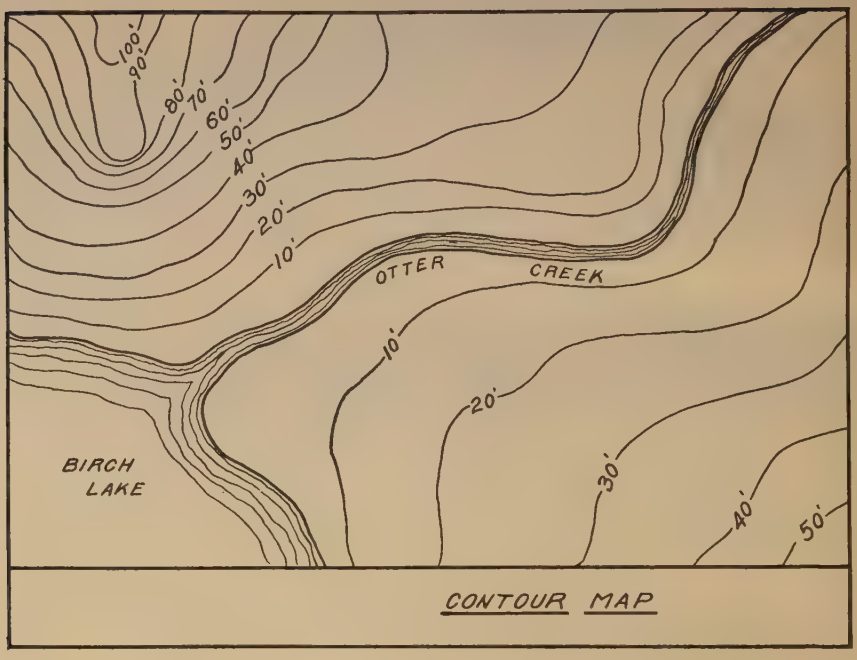


Plate 47B

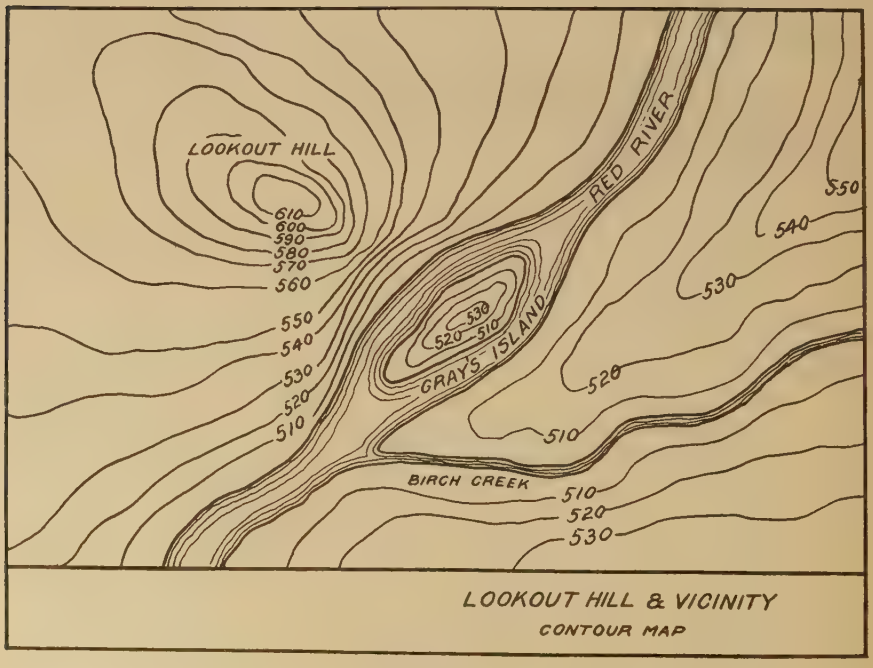


Plate 47A

ELECTRICAL DRAFTING
Lesson 48

I. *Purpose*

1. To learn something of the work of an electrical engineer.
2. To learn to draw and recognize the common conventional electrical symbols.

II. *General Information: Electrical Engineering*

When Benjamin Franklin, in his amateur experiments, drew sparks from a key attached to a kite string during an electrical storm, electricity was a force but little understood and of no practical value. Since that time our knowledge and use of electricity have developed in such a seemingly magical way that, should electricity be suddenly taken away from us, the wheels of industry would stop with disastrous results to the people.

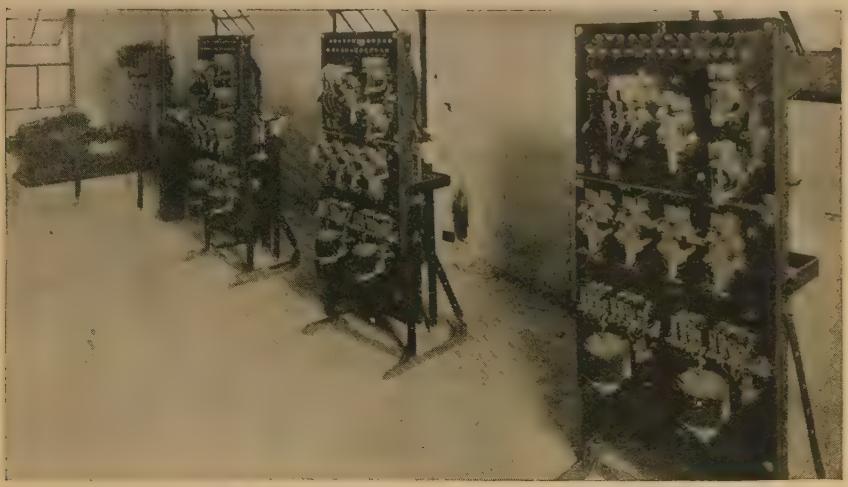


Fig. 51. Electrical switchboards used for controlling passenger elevators (Courtesy Cutler-Hammer Mfg. Co., Milwaukee, Wis.)

Science and invention are moving ahead so rapidly in the electrical fields, that most of us are usually months or even years behind in our knowledge of what is taking place.

It is the job of the electrical engineer to apply all his knowledge to practical use. For example, he designs and supervises the building of hydroelectric power plants, he designs electrical machines, he plans and supervises the construction of transmission lines, he designs electrical devices, such as switches, transformers, and the like, he supervises the installation of electrical equipment, and so on. Like other engineers, he must be able to express his designs by means of mechanical drawings.

Electrical engineering is one of the most interesting of the technical professions. Because of this fact, it is becoming a field in which there is a great deal of competition. Young men are rushing into the work in large numbers. This, of course, means that only the most capable students can hope for success. Before entering upon a course of training, a young man should assure himself that he has a real interest in science and mechanics, and that he has more than ordinary ability in mathematics.

Sources for further study:

Visit an electric power plant.
Wade: *Everyday Electricity.*
Jones: *Essentials of Applied Electricity.*

III. *The Problem*

To study the wiring symbols, and to copy one of Plates 48C, B, or A.

IV. *Suggestions for Procedure*

At the option of the instructor, these plates may be done free-hand to save time.

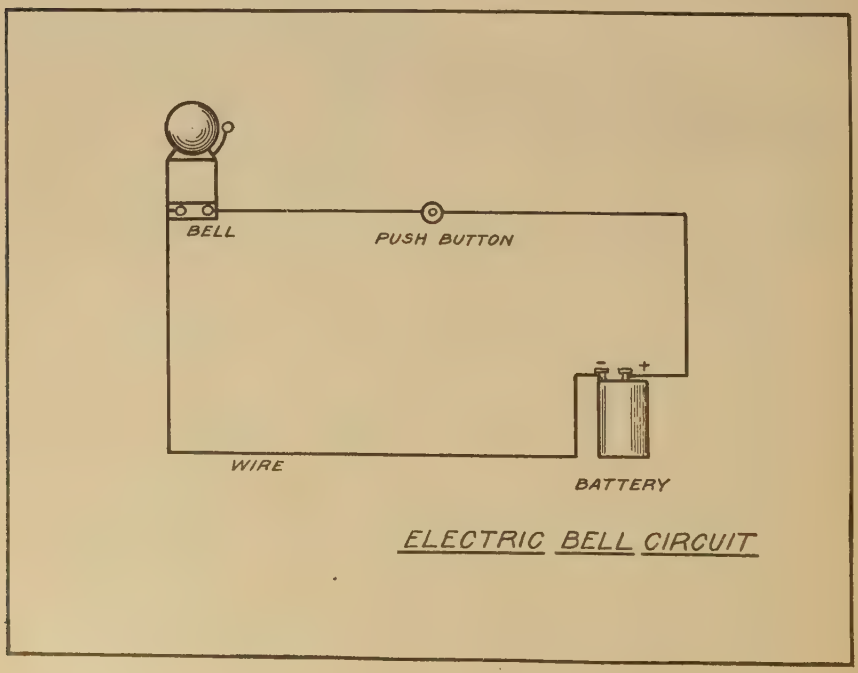


Plate 48C

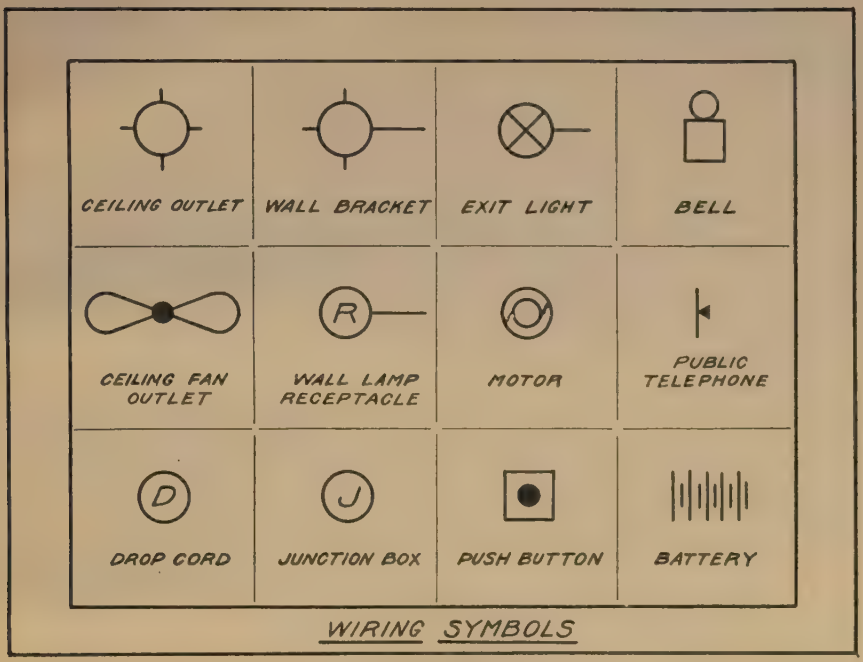


Plate 48B

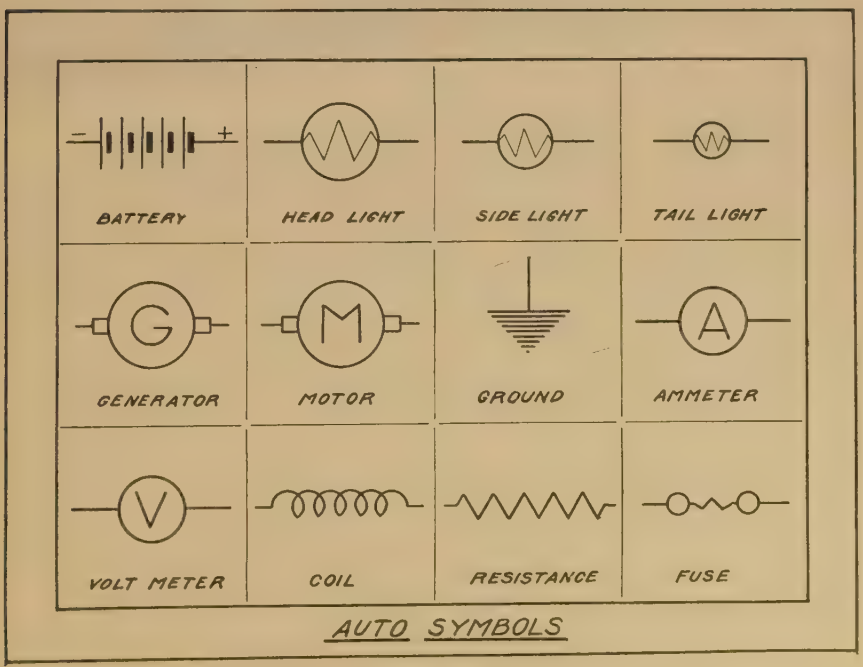


Plate 48A

Lesson 49

I. *Purpose*

1. To learn something about the relationship of drafting to radio and the work of the electrical engineer.
2. To make and read a drawing of a radio hook-up.

II. *General Information: Radio Engineering*

Radio telephony and radio telegraphy are branches of the general field of electricity. It is needless to say that since the development of radio broadcasting, there has been a vast growth in the manufacture of radio receiving apparatus unequaled by anything in our industrial history. This great expansion has opened another specialty to the electrical engineer and has inspired a great deal of invention and scientific study. The result is that theoretical knowledge is far ahead of actual applications to practical work. Since application is the job of the engineer, there is much to be done in radio.

However, the same difficulty is true in radio engineering as in general electrical engineering; that is, more young men enter the field than are needed. Hence, unless a student feels that he has unusual talent for the work, radio may not be the best type of work for which to prepare.

Much of the development of radio must be accredited to the work of amateur experimenters, and, although fewer people are now building their own sets, trying for long distances and that sort of thing, it is true that practically every household has a receiving set. It is, therefore, to the advantage of everyone to know a little about radio. In order to learn about radio, or to make use of what one does know, it is necessary to be able to read a conventional drawing of a radio hook-up.

We cannot take the space here to explain the use and purpose of each part of a radio set. We are merely interested in the language through which radio ideas are expressed. A study of the accompanying plates will supply the meanings of symbols which will make the reading of a hook-up simple enough, if one has some understanding of radio principles.

Sources for further study:

Manly: *Drake's Radio Encyclopedia.*

III. *The Problem*

To study the radio symbols in Supplementary Plate 49, and make a drawing of a radio receiving-set circuit.

IV. *Suggestions for Procedure*

1. All curved lines may be made free-hand.
2. Many other similar drawings may be found in current copies of the radio magazines.

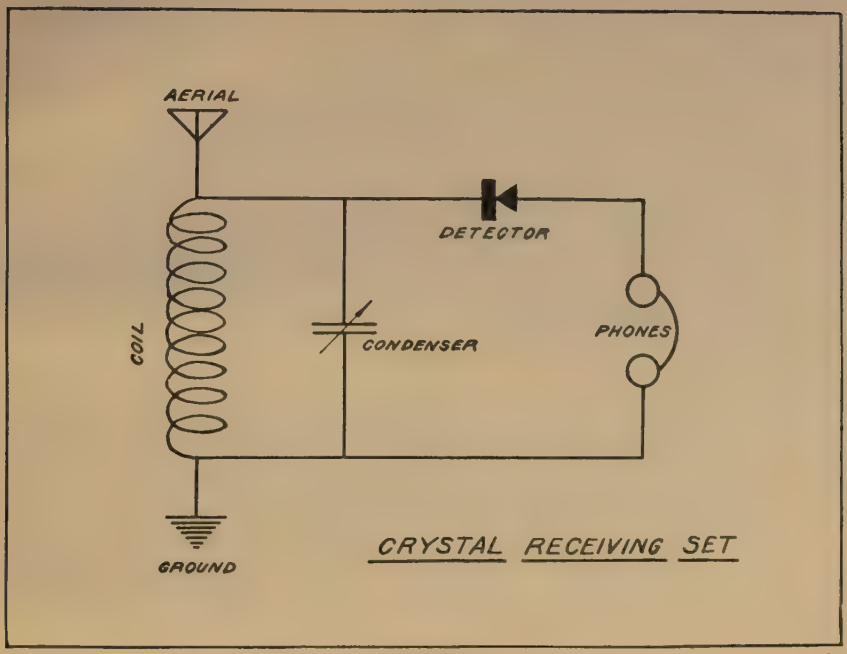


Plate 49C

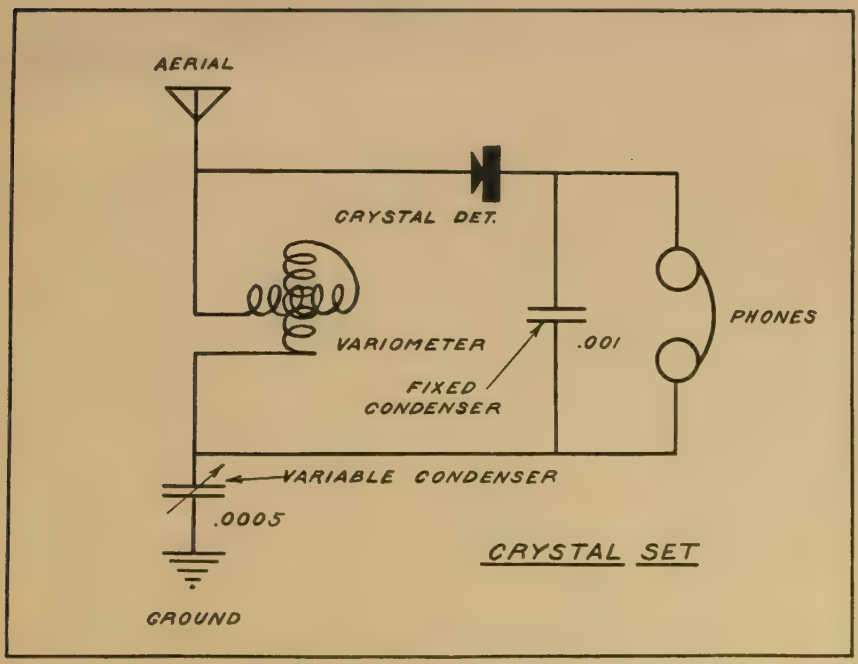


Plate 49B

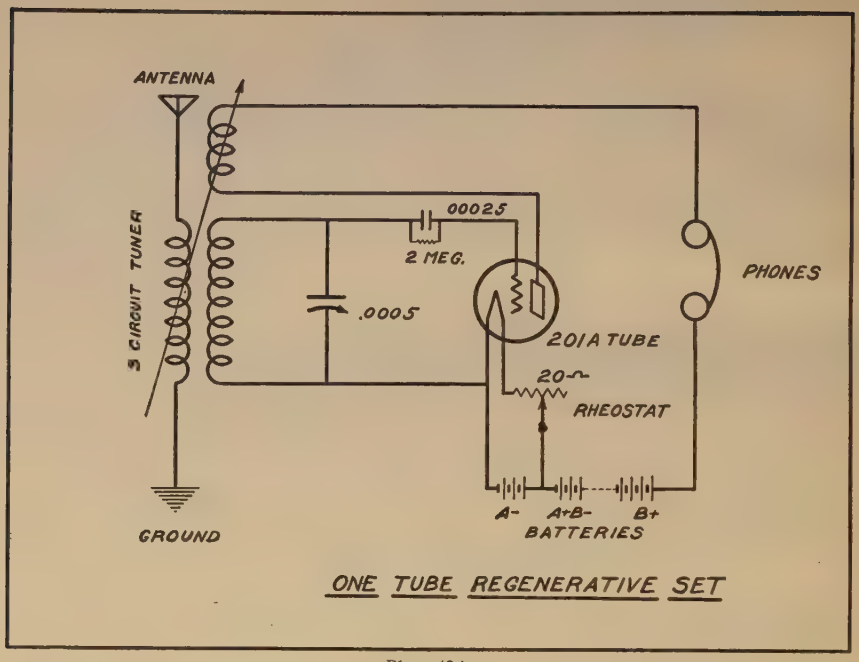
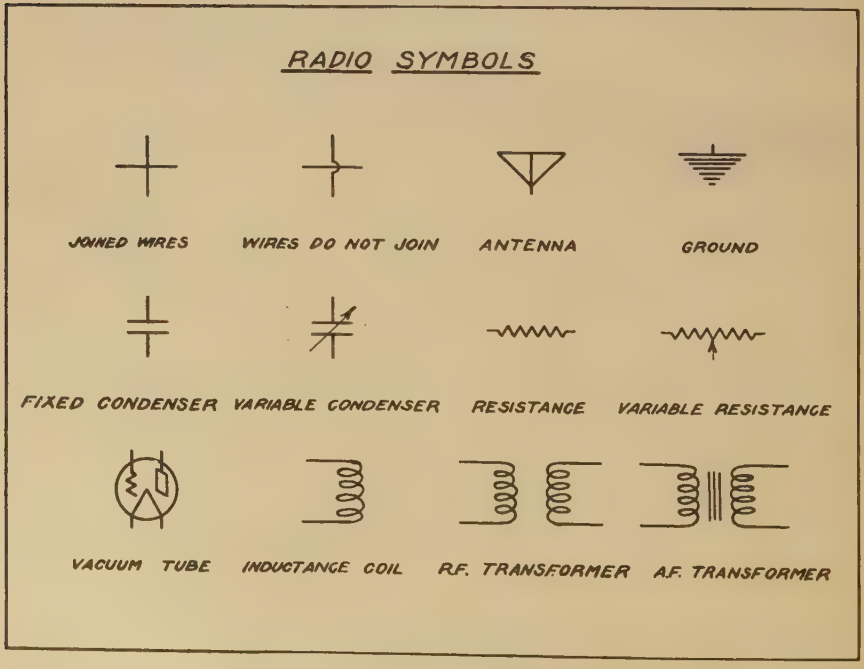


Plate 49A



Supplementary Plate 49

STATISTICAL CHARTS, GRAPHS, AND DIAGRAMS

Lesson 50

I. *Purpose*

1. To learn how and why charts and graphs are used.
2. To make a simple bar diagram.

II. *General Information: Use of Diagrams and Graphs*

In magazines, newspapers, and books, we frequently encounter diagrams or graphs. These are used because they represent certain kinds of facts much more clearly, quickly, and in less space than could be done in any other way. For example, we might show the relationship of populations in a number of different countries by drawing parallel lines of different lengths, the length of each line being determined by the number of people in the respective country. This same information might be given in printed form, but the graph or chart gives all the information at one glance.

There are many kinds of graphs, several of which are illustrated in this lesson. Limited space does not permit us to illustrate all of these, but the purpose of them all is the same; namely, to give a "glance value" to a set of complicated facts.

Many examples of graphs may be found in newspapers, statistical reports, books, and magazines — especially in those magazines which deal with business.

III. *The Problem*

To draw a diagram like one of those shown in Plates 50C, B, or A. Instead of the facts used here, gather facts about your own school. For example, in the "pie plate" diagram (Plate 50C), one might show the number of pupils enrolled in each of the seventh, eighth, ninth, tenth, etc., grades in the school. In the "bar" diagrams (Plates 50B and A), the enrollment in mechanical-drawing classes for the past five or ten years might be shown.

IV. *Suggestions for Procedure*

1. In Plate 50C, draw the circles 4″ in diameter. The proportion that any sector of a circle is of the whole should be measured on the circumference. Great accuracy is not required.

2. In Plate 50B, the bars and spaces should be ¼″. The vertical lines are 1¼″ apart.

3. In Plate 50A, the bars and spaces are ¼″. The horizontal lines are spaced ¾″ apart.

4. The bars in the diagrams may be filled in with pencil, crosshatched, or merely left blank.

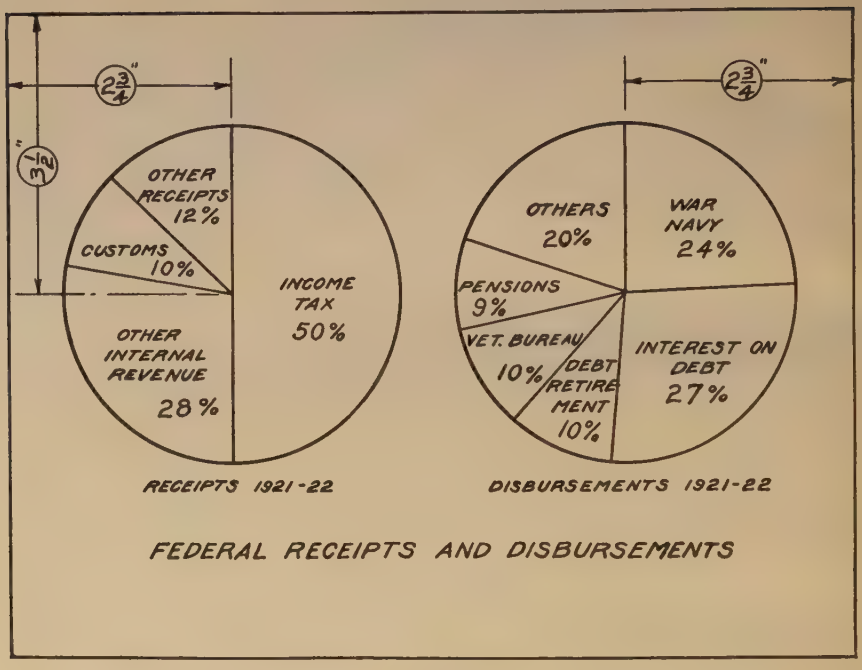


Plate 50C

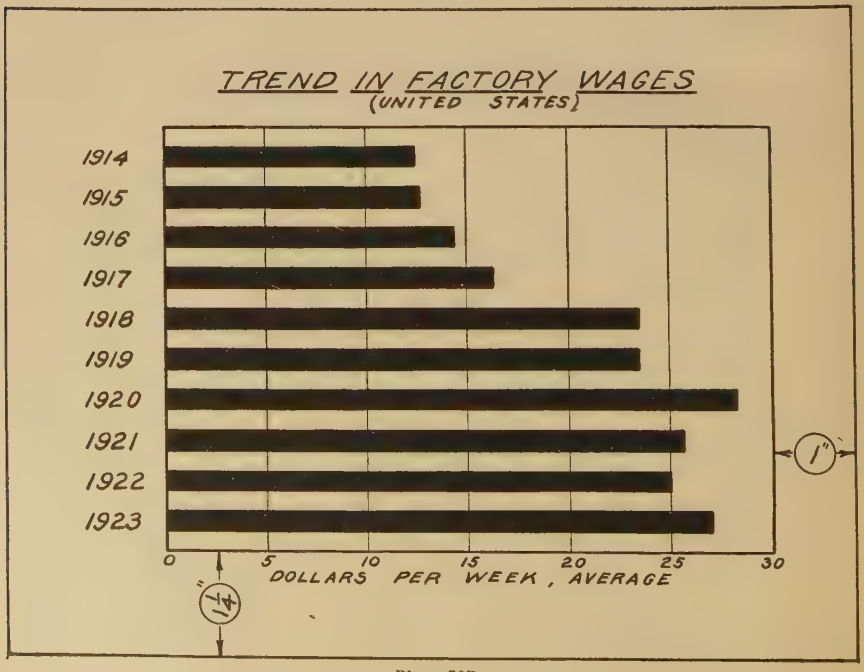


Plate 50B

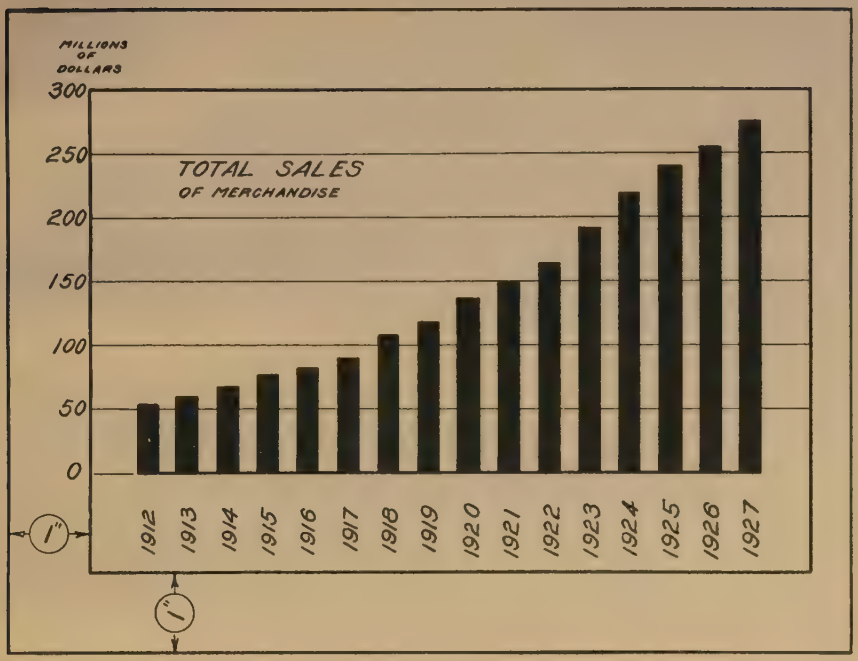

MILLIONS OF DOLLARS
300
250
200
150
100
50
0
TOTAL SALES
OF MERCHANDISE
1"
1"
1912
1913
1914
1915
1916
1917
1918
1919
1920
1921
1922
1923
1924
1925
1926
1927

Plate 50A

Lesson 51

I. *Purpose*

To learn how to make and use some of the more common line graphs.

II. *General Information: Use of Line Graphs*

When two sets of facts are to be shown in relation to each other, it is common to use one of several types of line graphs. These consist of two lines or axes drawn at right angles to each other. In Plate 51B, the horizontal axis represents time in years, while the vertical line represents per cent of increase based on the year 1914. From this figure we see at a glance that both "number of consumers" and "amount of sales" have increased quite constantly since 1914. We also see that sales have increased faster than number of consumers. Then we can read as much more detail as we wish. For example, in 1920, number of consumers had increased 60 per cent, while sales had increased 120 per cent; or in 1926, these figures were 145 per cent and 225 per cent respectively.

Plate 51A shows the changes in methods of locating the valves in automobile engines.

Questions

1. In 51C, which number of main bearings in 6-cylinder cars has shown a steady increase between 1925 and 1929? Which has shown a steady decline? Which is least frequently used?
2. In 51B, which year shows a sharp decrease in gas sales? The graph shows that "gas sales" have increased faster than "number of consumers." Does this mean that each consumer used more or less gas in 1926 than in 1914? How much more or less?
3. As shown in Plate 51A, which type of cylinder head was used more than three fourths of all makes of automobile engines in 1928? Which has shown the greatest increase since 1913? Which the greatest decrease?

III. *The Problem*

To make a line graph like one of those shown in Plates 51C, B, or A. If possible, select other facts to represent in place of those used in the examples.

IV. *Suggestions for Procedure*

1. Locate points on vertical lines and connect with short straight lines.
2. In Plate 51C, the horizontal lines are spaced ½″ and the vertical lines 2″.
3. In Plate 51B, the rectangles are ½″ x ¾″.
4. In Plate 51A, the squares are ½″ x ½″.

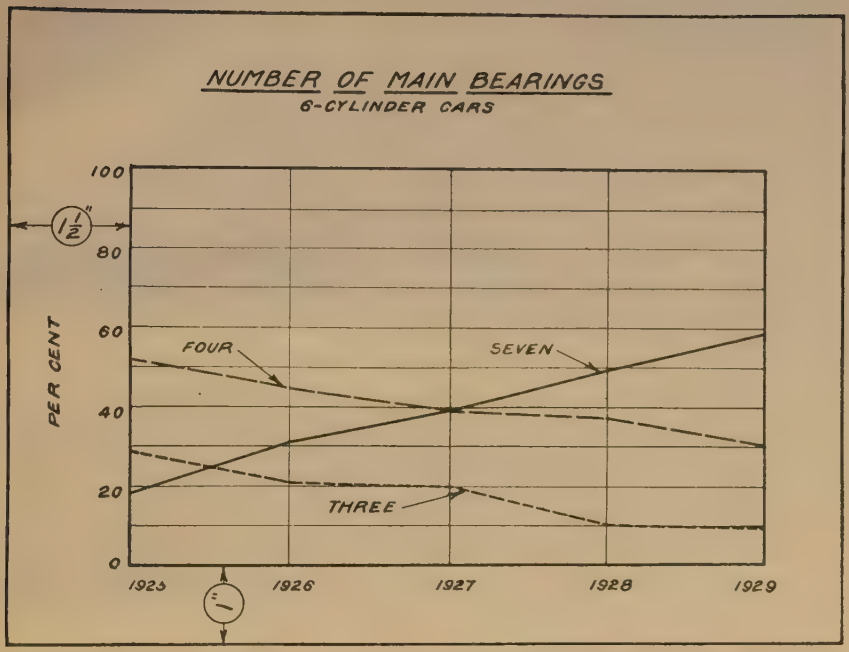


Plate 51C

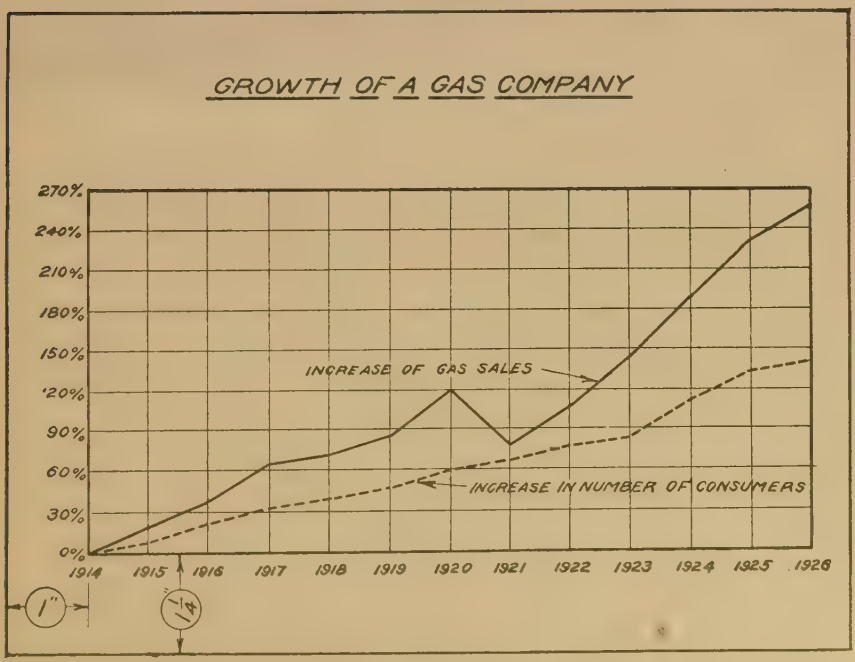


Plate 51B

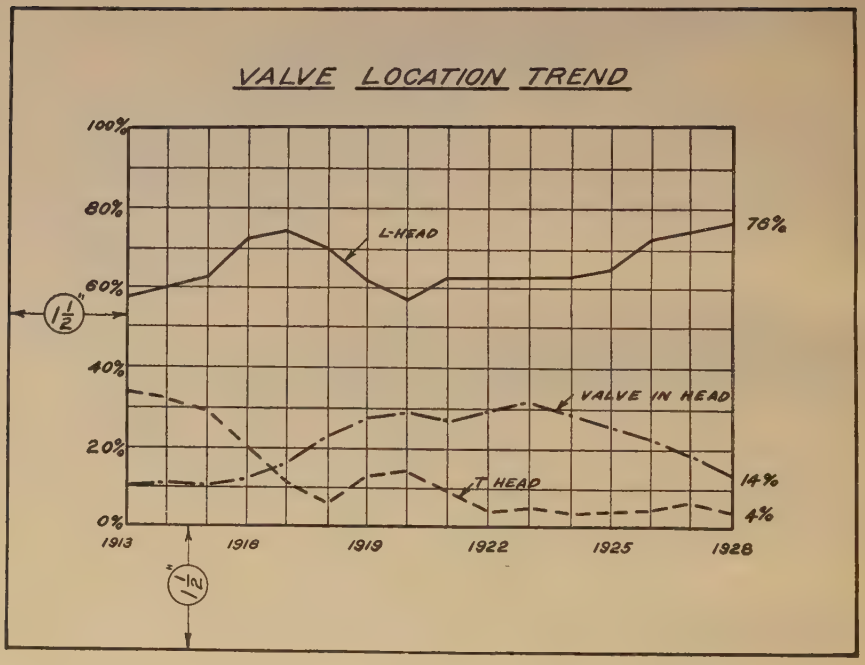


Plate 51A

Suggestive Test 6

Test items similar to those illustrated in the preceding tests may be used here.

Suggestions for Final Examination

It is suggested here that items be selected from the preceding six tests on a basis of greatest frequency of student errors. This test should contain several different kinds of test items. About one hundred items might be regarded as a practical minimum number.

In addition, one or more of the standardized tests in mechanical drawing listed below should be given, in order to obtain comparisons with established norms.

D. W. Castle: *Mechanical Drawing Test.*

M. L. Laubach and George K. Wells: *Mechanical Drawing Test.* (100 true-false items.)

Nash-Van Duzee: *Mechanical Drawing Test.*

Arthur A. Strong